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SPRING HOLDING CONNECTORS

The present invention relates to canted coil springs that are mounted in grooves that can either be disposed in a housing or the shaft for the purpose of holding such shaft or housing from movement which can be axial or rotary and in some cases, permit the passing of current from the housing through the spring onto the shaft and vice versa. Retaining a shaft or a housing offers some significant advantages in case where a certain force needs to be developed to hold a piston or shaft and at the same time provide other benefits, such as electrical conductivity, shielding against EMI and others.

Connectors used in holding applications have been described extensively, as for example, US patent 4974821, 5139276, 5082390, 5,545,842, 5,411,348 to Balsells, and others. All of these patents are to be incorporated herewith by this specific references thereto.

Of these cited U.S. Patents, 4,974,821 generally describes canted coil springs and a groove for orienting the spring for major axis radial loading for enabling a specific preselected characteristic in response to loading of the spring.

U.S. 5,082,390 teaches a canted coil spring for holding and locking a first and second number to one another.

U.S. 5,139,276 discloses a radially loaded spring in a groove for controlling resilient characteristics of the spring.

U.S. 5,411,348 and 5,545,842 teach spring mechanisms which preferentially lock two members together.

None of the cited references or any prior art provides for controlling shaft mobility within a bore.

This patent invention provides for various types of novel groove designs disposed in a piston, a shaft, and/or housing. Different spring design configurations are provided that affect holding, force variation, resistivity variation, and other variations under static and dynamic loading conditions between the housing, the spring, and the shaft by appropriate groove, spring and material combinations.

SUMMARY OF THE INVENTION

A spring holding connector in accordance with the present invention generally includes a housing having a bore therethrough with shaft rotatably and/or slidably received within the bore.

A circular groove is formed in either the bore or the shaft and a circular spring is disposed in the groove for slidably holding the shaft within the bore. Importantly, the

groove is sized and shaped, in combination with a spring configuration, for controlling shaft mobility within the bore.

This causes movement of the shaft within the bore to require differing forces dependent upon direction of shaft movement.

In one embodiment of the present invention, a spring is turnable within the groove for causing forces required to move the shaft within the bore and be dependent upon the direction of the movement. In another embodiment, the spring is compressible within the groove for causing forces required to move the shaft within the bore to be dependent upon a direction of movement. Both turning and compression of the spring in combination further, in combination, provide for a differentiation of forces necessary to move the shaft within the bore to be dependent upon the direction of movement.

Such movement may be axial and further the spring may be turnable in the groove for enabling electroconductivity between the shaft and the housing to be improved by removing oxidation which may form on the spring. In this embodiment, the groove may include an uneven bottom for scraping the spring as the spring turns therepast.

In accordance with the present invention, the spring may be a counterclockwise radial spring or a clockwise radial spring depending upon the shaft mobility requirements.

Alternatively, the spring may be an axial spring having a back angle at an inside diameter of the spring coils and a front angle on an outside diameter the spring coils.

Alternatively, the spring may be an axial spring having a back angle on an outside diameter of the springs, coils and a front angle on an inside diameter of the spring coils. This again is important in providing the differential force requires as hereinabove noted.

More specifically, the groove may be sized and shaped for causing a combination of the spring combination a force required to move the shaft in one axial direction to be greater than about 300% of the force required to move the shaft in an opposite axial direction. This force differentiation may be as high as 1200% or more depending upon a groove and a spring selection as hereinafter set forth.

In one embodiment of the present invention, the groove has a tapered bottom and in another embodiment the groove may have a flat bottom.

The groove further may include a V-bottom, a tapered V-bottom, a semi-tapered V-bottom, or a round bottom with a shoulder thereon.

In addition, the connector may include the grooves with inverted V-bottoms with a different angles as subtending sides of the groove. A dovetail groove may also be utilized and the

groove may include an inwardly facing lip disposed opposite a groove bottom all of the groove, all such embodiments being hereinafter described in greater detail.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and features of the present invention will be better understood by the following description when considered in conjunction with the accompanying drawings in which:

Figures 1a-1e show different positions of a counter clockwise radial spring;

Figures 2a-2c show a counter clockwise radial spring and a flat bottom housing groove;

Figures 3a-3c show a clockwise radial spring and a flat bottom housing groove;

Figures 4a-4b shows a RF clockwise axial spring and a tapered bottom groove;

Figures 5a-5d shows an RF clockwise axial spring mounted in a tapered bottom groove;

Figures 6a-6c are similar to Figures 4a-4d and 5a-5d with the spring mounted in a piston groove;

Figures 7a-7c are similar to Figures 6a-6c shown a different direction of shaft movement;

Figures 8a-8c and 9a-9c make a comparison to the configuration shown in Figures 4 and 5 in which an F axial spring is utilized;

Figures 10a-10c and 11a-11c shown an F spring mount in a piston;

Figures 12a-12g show a counter clockwise radial spring turn 90° clockwise into a counter clockwise axial F spring and assembled in a groove with the groove width smaller than the coil height;

Figures 13a-13g show a counter clockwise radial spring turn 90° clockwise into a clockwise axial RF spring assembled in a groove with the groove width smaller than the coil height;

Figures 14a-14g show a counter clockwise radial spring turn 90° clockwise into a clockwise axial RF spring and assembled in a groove with a groove width smaller than the coil height;

Figures 15a-15g show a counter clockwise radial spring turn 90° clockwise into a counter clockwise axial F spring and assembled in a groove with a groove width smaller than the coil height;

Figures 16a-16b and 17a-17b show axial RF and F springs with a shaft shown moving in a concave direction of the spring ID as shown in Figures 16a and 16b and Figures 17a-17b showing the shaft moving in a convex direction of the spring ID;

Figures 18 and 19 illustrates that when a pin is moved away from a turn angle "A" the running force developed a substantially less than when the pin moves toward the tapered angle "A", with the spring turning clockwise;

Figures 20a-20c show radial spring in which the free spring outside diameter is greater than the bore outside diameter;

Figure 21a-21c shows a radial spring in which the free spring outside diameter is equal to the bore outside diameter;

Figures 22a-22c show radial spring mounted in a piston in which the spring ID is smaller than the piston groove diameter;

Figures 23a-23c show a radial spring mounted on a piston in which the spring ID is equal to a piston groove diameter;

Figure 24 shows the radial spring compression with various housing bore diameters;

Figure 25 illustrates a constant housing bore diameter with a variable shaft diameter;

Figures 26a-26b illustrate F springs versus RF springs mounted in a housing;

Figures 27a-27b show F springs versus RF springs mounted on a piston;

Figures 28a-28c show a variation of an RF spring diameter and its effect on forces;

Figures 29a-29c compare the variation of an F spring diameter and its effect on force; and

Figures 30-37 show different kinds of groove spring configurations having a flat bottom groove, both on the housing and on the piston using axial springs and a groove in which the groove width is smaller than the groove height.

DETAILED DESCRIPTION

An overview or general description of spring and groove configurations as well as various definitions to enable and understanding of the present invention is appropriate. In the present application, the groove configurations have been divided into two types: one type with the spring retained in the housing as shown in Tables 1a-1j and the other with the spring retained in a shaft, as shown in Tables 2a-2h which

also provides design features and characteristics of the holding connectors in accordance with the present invention.

The springs are divided in two types: a radial spring and an axial spring.

Definition of radial canted coil spring. A radial canted coil spring has its compression force perpendicular or radial to the centerline of the arc or ring.

Definition of axial canted coil spring. An axial canted coil spring has its compression force parallel or axial to the centerline of the arc or ring.

The spring can also assume various angular geometries, varying from 0 to 90 degrees and can assume a concave or a convex position in relation to the centerline of the spring.

Definition of concave and convex. For the purpose of this patent application, concave and convex are defined as follows: The position that a canted coil spring assumes when a radial or axial spring is assembled into a housing that has a groove width smaller than the coil height and upon passing a pin through the ID of such spring, the spring is positioned by the inserting pin so that the ID is forward of the centerline of the minor axis of the spring cross section is a concave position.

When the spring is assembled in the piston, upon passing the piston through a housing, the spring is positioned by the housing so the OD of the spring is behind the centerline of the minor axis of the spring cross section is a convex position.

The spring-rings can also be extended for insertion into the groove or compressed into the groove. Extension of the spring consists of making the spring ID larger by stretching or gartering the ID of such spring to assume a new position when assembled into a groove or the spring can also be made larger than the groove cavity and compressed around the outside diameter to assume a smaller outside diameter to fit the groove inside diameter.

Canted coil springs are available in radial and axial applications. Generally, a radial spring is assembled so that it is loaded radially. An axial spring is generally assembled into a cavity so that the radial force is applied along the major axis of the coil, while the coils are compressed axially and deflect axially.

<u>Radial springs</u>. Radial springs can have the coils canting counterclockwise (Table 1a, row 2, column 6) or clockwise (Table 1a, row 3, column 6). When the coils cant counterclockwise, the front angle is in front (Figure 2c) with the back angle in the back and when the coils cant clockwise (Figure 3a), the back angle is in the front and the front angle is in the back. Upon inserting a pin or shaft through

the inside diameter of the spring with such spring mounted in the housing in a counterclockwise position (Figure 2c), the shaft will come in contact with the front angle of the coil and the force developed during insertion will be less than when compressing the back angle with the spring in a clockwise position. The degree of force will vary depending on various factors as hereinafter discussed. The running force will be about the same.

Radial springs may also be assembled into a cavity whose groove width is smaller than the coil height. Assembly into such cavity can be done by turning the spring coils clockwise or counterclockwise 90° and assembling the spring into the cavity. Under such conditions, the spring will assume an axial position, provided that the groove width is smaller than the coil height. Under such conditions, the insertion and running force will be slightly higher than when an axial spring is assembled into the same cavity. The reason is that upon turning the radial spring at assembly, a torsional force is created, requiring a higher insertion and running force to pass a shaft through the inside diameter or other groove configuration of the spring.

<u>Axial springs</u>. Axial springs can be RF (Table 1a, row 5, columns 5 and 6) and F (Table 1a, row 6, columns 5 and 6). An RF spring (Table 1a, row 5, column 6) is defined as one in which the spring ring has the back angle (Figure 1e) at the ID of the coils with the front angle on the OD of the coils. An

F spring (Table 1a, row 6, column 6) has the back angle at the OD and the front angle at the ID of the coils.

Turn angle ring springs. (Table 1h, row 4, column 6 to Table 1i, row 4, column 6) The springs can also be made with a turn angle and can assume a position from 0 to 90 degrees. It can have a concave (Figure 4c) or a convex (Figure 5c) position when assembled into the cavity, depending on the direction in which the insertion pin is assembled that can affect the insertion assembly and running force.

Assembly of axial spring ring into a cavity. F type axial springs always develop a higher insertion and running force than an RF spring. The reason being is that in an F spring back angle is always located at the OD of the spring, which develops a higher force.

Types of grooves that may be designed. Grooves may be classified in different designs.

Flat groove. (Table 1a, row 2, column 3 and row 3 column 3) The simplest type of groove is one that has a flat groove and the groove width is larger than the coil width of the spring. In such case, the force is applied radially.

'V' bottom groove. (Table 1a, row 4, column 3) This type of groove retains the spring better in the cavity by reducing axial movement, increasing the points of contact, which enhances electrical conductivity and reduces the variability

of such conductivity. The groove width is larger than the coil width. The spring force is applied radially.

Grooves for axial springs. (Table 1a, row 5, column 2 to Table 1b, row 5, column 2) Grooves for axial springs are designed to retain the spring at assembly better. In such cases, the groove width is smaller than the coil height. At assembly, the spring is compressed along the minor axis axially and upon the insertion of a pin or shaft through the ID of the spring the spring, the coils deflect along the minor axis axially.

There are variations of such type of grooves from a flat bottom groove to a tapered bottom groove or modifications thereof.

Axial springs using flat bottom groove. In such cases, the degree of deflection available on the spring is reduced compared to a radial spring, depending on the interference that occurs between the coil height and the groove width.

The greater the interference between the spring coil height and the groove, the lower the spring deflection and the higher the force to deflect the coils and the higher the insertion and running forces on shaft/pin insertion.

In such cases, the spring is loaded radially upon passing a plunger through the ID of such spring (Table 1a, row 5 to Table 1f, row 3) and the deflection occurs by turning the

spring angularly in the direction of movement of the pin. An excessive amount of radial deflection may cause permanent damage to the spring because the spring coils have "no place to go" and butt.

Axial springs with grooves with a tapered bottom. (Table 1c, row 4, to Table 1d, row 5) A tapered bottom groove has the advantage that permits the spring to deflect gradually compared to a flat bottom groove. When a pin is passed through the ID of the spring while such spring is mounted in the groove, it will deflect in the direction of motion and the running force may remain about the same or vary depending on the direction of the pin and the type of spring. Lower force will occur when the pin moves in a concave spring position (Figure 16b) and higher force (Figure 17b) that when the pin moves in a convex spring position.

Tapered bottom grooves have the advantages that they have a substantial degree of deflection, which occurs by compressing the spring along the minor axis, thus allowing for a great degree of tolerance variation as compared to flat bottom grooves.

Grooves can be mounted in the piston or in the housing, depending on the application. Piston mounted grooves are shown in described Tables 2a - 2h.

Expanding a radial spring or compressing such spring. A radial spring ring can be expanded (Figure 21a, 21b, and 21c)

from a small inside diameter to a larger inside diameter and can also be compressed from a larger OD to a smaller OD (Figures 23a, 23b, and 23c) by crowding the OD of such spring into the same cavity. When expanding a spring ring, the back angle and front angles of the spring coils decrease (See Figures 1a to 1e), thus increasing the connecting and running force. When compressing a radial spring OD into a cavity, which is smaller than the OD of such spring, the coils are deflected radially, causing the back and front angles to increase. The increase of such angles reduces the connect and running force when passing a pin through the ID of such spring.

The following designs are incorporated into the present patent application by this specific reference thereto as follows:

1) U.S. patent 4,893,795 sheet 2 Figures 4, 5A, 5B, 5C, 5D, 5E, 6A and 6B;
2) U.S. patent 4,876,781 sheet 2 and sheet 3 Figures 5A, 5B, and Figure 6.
3) U.S. patent 4,974,821 page 3 Figures 8 and 9
4) U.S. patent 5,108,078 sheet 1 Figures 1 through 6
5) U.S. patent 5,139,243 page 1 and 2 Figures 1A, 1B, 2A, 2B and also Figure 4A, 4B, 5A, and 5E
6) U.S. patent 5,139,276 sheet 3 Figures 10A, 10B, 10C, 11A, 11B, 12A, 12B, 12C, 13A, 13B, and 14

7) U.S. patent 5,082,390 sheet 2 and 3, Figures 4A, 4B, 5A, 5B, 6A, 6B, 7A, 7C, 8A, 8B

8) U.S. patent 5,091,606 sheets 11, 12, and 14. Figures 42, 43, 44, 45, 46, 47, 48, 48A, 48B, 49, 50A, 50B, 50C, 51A, 51B, 51C, 58A, 58B, 58C, 58D.

9) U.S. patent 5,545,842 sheets 1, 2, 3, and 5. Figures 1, 4, 6, 9, 13, 14, 19, 26A, 26B, 27A, 27B, 28A, 28B.

10) U.S. patent 5,411,348 sheets 2, 3, 4, 5, and 6. Figures 5A, 5C, 6A, 6C, 7A, 7C, 7D, 8A, 8B, 8C, 9A, 9C, 10C, 11, 12 and 17.

11) U.S. patent 5,615,870 Sheets 1-15, Sheets 17-23 with Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135.

12) U.S. patent 5,791,638 Sheets 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18,

19, 20, 21, 22, 23. Figures 1-61 and 66-88 and 92-135.

13) U.S. patent 5,709,371, page 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23. Figures 1-61 and 66-88 and 92-135.

The present application which is described in conjunction with Tables 1a-1j and Tables 2a-2h.

The following is a detailed description of this patent application. The general description is provided in Tables 1a-1j, Tables 2a-2h and Figures 1-37.

TABLES 1a-1j Housing Mounted Designs for Holding and Other Applications

This consists of 40 different types of grooves and spring geometries in which the spring is mounted in the housing, using different spring configurations different groove variations, which develop various spring forces and different insertion and running forces.

Table 1a-1j

Figure 1 shows a flat bottom groove with a radial spring.

Table 1a, row 2, column 2 shows an assembly with a spring mounted in a housing with a shaft moving back and forth axially.

Table 1a, row 2, column 3 shows a schematic of the housing.

Table 1a, row 2 column 4 shows the position of the radial spring in a free assembled position and also in the radially spring-loaded position with the position of the front angle of the spring in relation to the groove.

Table 1a, row 2, column 5 shows the general dimensions of the coil width and the coil height with the ID of such spring.

Table 1a, row 2, column 6 shows the front pictorial view of the radial spring canting counterclockwise.
Some of the features of these designs are: (1) the groove width is larger than the coil width. (2) the insertion force will lower because the front angle is the front of the coil. (3) the running axial force to move the pin forward and back has approximately the same running force. This type of gland is relatively easy to fabricate and its geometry allows for large radial spring deflection. The gland can accommodate different types of spring loads depending on the coil height and wire diameter and the ratio of the coil height to the wire diameter. The spring can be mounted in the groove clockwise or counterclockwise. The clockwise radial spring has a front angle on the back. (See Table 1a, row 2, column 2 and Figures 3a; 3b; 3c) Counterclockwise radial spring has the front angle in the front. (See Figures 2a, 2b; 2c). The main disadvantage of a flat bottom groove is that this spring can shuttle back and forth and in applications involving conductivity, the conductivity is subject to variations due to such shuttling, thus causing electrical variability.

Table 1a, row 3 shows the spring mounted 180° from Figure 1 in a clockwise position.

Table 1a, row 4, describes a 'V' bottom radial spring.

Table 1a, row 4, column 2 shows a spring mounted in a 'V' groove cavity where the pin can and move back and forth axially.

Table 1a, row 4, column 3 shows a detailed portion of the groove, showing a 30° angle on the groove. The 30° angle has been found to work satisfactorily. However, other angles may be used ranging from 1° to 89°, depending on the application.

Table 1a, row 4, column 4 shows the spring in a free position mounted in the groove cavity and also shows the spring coil in a loaded position. Features of this spring is that the groove width is larger than the coil width.

- Running forces are generally the same in the backward and forward directions.
- Advantages: Reduces spring shuttling.
- Enhances electrical conductivity due to more areas of contact.
- Enhances less electrical variability due to better spring retention in the groove.
- Disadvantages:

- Gland is more difficult to fabricate compared to a flat bottom groove as indicated in Table 1a, row 2, column 3.

Table 1a, row 4, column 5 shows a cross sectional view showing the coil heights and coil width and ID of such spring.

Table 1a, row 4, column 6 shows a pictorial view of a spring in a counterclockwise direction.

Radial springs can be mounted clockwise or counterclockwise. Counterclockwise springs have the front angle on the front and the back angle on the back. Clockwise radial springs have the front angle on the back and the back angle on the front. (Table 1a, row 3, column 6)

Table 1a, row 5 describes a Flat bottom axial groove with an axial RF spring.

Table 1a, row 5, column 2 shows an assembly view of a spring in a flat bottom groove loaded radially, allowing the spring to assume a concave position in the initial direction of inserting the pin.

Table 1a, row 5, column 3 shows a view of the cross section of the groove.

Table 1a, row 5, column 3 shows the spring in an assembled position with the coils being squeezed axially into the groove. Table 1a, row 5, column 4 also shows the spring

position after initial insertion in the initial direction of the pin.

FEATURES:

1) Groove width smaller than the coil height.
2) Axial spring being used.
3) Variable axial forces. Forward running frictional force is generally the same as the backward running force.

Advantages. Enhanced electrical conductivity is due to more contact area. Reduced electrical variability due to better retention of the spring in the cavity.

Disadvantages.

- Reduced spring deflection compared to a radial spring.
- Tighter gland width tolerances required.

Table 1a, row 5, column 5 shows the general dimensions of the coil and spring with the ID, coil width and coil height.

Table 1a, row 5, column 6 shows a pictorial view on an RF axial spring.

Axial springs consist of RF and F springs.

RF has the coils canting clockwise with the back angle at the ID and the front angle at the O.D. (Table 1a, row 5, column 5 and 6)

Table 1a, row 6 describes a configuration like the configuration describe in Table 1a, row 5 except that an F spring is used instead of an RF spring.

F has the coils canting counterclockwise and the back angle on the OD and the front angle on the ID. (Table 1a, row 6, column 5 and 6)

Radial springs can be assembled in an axial manner. Table 1b, rows 7, 8, 9 and 10 describe radial springs turned into axial springs

Table 1b, row 2 describes a flat bottom axial groove with a radial spring mounted into RF position.
Table 1b, row 2, column 2 shows a radial spring mounted in an axial manner.
Table 1b, row 2, column 3 shows a cross section of the groove.
Table 1b, row 2, column 4 shows the radial spring coil mounted in an axial manner and shown also in a deflected manner.
Table 1b, row 2, column 5 shows the radial spring dimensions
Table 1b, row 2, column 6 shows a radial spring in a counterclockwise direction.

FEATURES:
(1) The groove width is smaller than the coil height, using a radial spring. (2) Radial spring mounted axially. (3) The force characteristics will be higher than the configuration described in Table 1a, row 5, column 6 because the shaft

travels against the torsional force of the spring as the spring tries to return to its free position.

Advantages. Enhanced electrical conductivity due to more contact area. Reduced electrical variability due to better retention of the spring in the cavity.

Disadvantage. Gland is more difficult to fabricate compared to a flat bottom.
Tighter gland width tolerances are required.

Table 1b, rows 3-10 shows the spring mounted in a flat bottom groove, however, the position that the axial spring assumes after being assembled in an axial manner is different.

Table 1b shows a counterclockwise radial spring turned 90° counterclockwise, becoming a counterclockwise F type spring, as indicated in columns 2, 4 and 6.

Table 1b shows a clockwise radial spring turned 90° counterclockwise, which becomes a clockwise RF spring, as indicated in columns 2, 4 and 6.

Table 1b shows a clockwise radial spring turned 90° clockwise, becoming a counterclockwise axial F spring as indicated in columns 2, 4 and 6.

Comparison between counterclockwise radial spring turned 90° into F and RF springs. See Table 1b, row 2 versus Table 1b, row 3.

Counterclockwise radial spring turned 90° clockwise into clockwise axial RF spring and assembled into a groove with the groove width less than coil height will yield lower connecting and running forces compared to the counterclockwise radial spring turned 90° into a counterclockwise axial F spring assembled into the same groove.

Comparison between clockwise radial spring turned 90° into F and RF axial springs. (See Table 1b, row 4 versus row 5). Clockwise radial spring turned 90° into clockwise RF spring and assembled into an axial groove (groove width smaller than coil height) will yield lower connecting and running forces compared to the clockwise radial spring turned 90° into a counterclockwise axial F spring assembled into the same groove.

Table 1b, row 6 is a variation of Table 1a, row 5. In Table 1b, row 6 a flat 'V' bottom groove is shown, which allows a greater degree of deflection of the coil. The groove width is smaller than the coil height, thus assuring retention of the spring. An RF or an F spring could be used in this design. The RF having the front angle on the OD will have a higher degree of deflection than the F spring that has the front angle on the OD.

Table 1c, row 2 shows a variation of Table 1b, row 6. In this case, the groove width is larger than the coil height, thus allowing a greater degree of deflection. However, the spring is not firmly retained in the cavity at assembly.

Table 1c, row 3 is a variation of Table 1b, row 6. In this case, the groove width is larger than the coil height, thus allowing a greater degree of deflection. The design can use an RF, F spring, radial or angular spring. Groove width can also be greater than the coil height and smaller than the coil width.

Table 1c, row 4 shows a variation of Table 1a, row 5. In this case, a semi tapered bottom groove is shown. The coil width is smaller than the coil height, thus retaining the spring in place and at the same time allows a high degree of coil deflection. This particular design allows a greater degree of contact of the coil with the housing, thus permitting enhanced electrical conductivity and reduced electrical variability.

Table 1c, row 6 is a variation of Table 1c, row 5, in which a tapered bottom groove is used and the groove width is smaller than the coil height to facilitate retention of the spring.

Table 1a, row 5 through Table 1c, row 5 shows the spring assembled into the cavity and the pin running in a concave direction.

Table 1d, row 2 shows a design like Table 1c, row 5, except that the pin or shaft has been turned around so that the pin approaches the spring in a convex position. By doing that there is a substantial increase in the insertion and running forces between the convex and concave position of the spring coils with the convex position yielding substantially higher running force than moving the pin in a concave position. (This is further discussed as shown in Figures 16-17). In this case, an RF spring is shown.

Table 1d, row 3 shows the same design as Table 1d, row 2, except that an F spring is shown with a front angle at the inside of the spring coil. In this case, the same as in Table 1d, row 2, the convex insertion and running force is substantially higher than the reverse concave force, except that the F spring produces substantially higher insertion and running forces than the RF spring. (Further details will be hereinafter discuss in connection with Figure 16 and 17 and Table 3)

Table 1d, row 4 shows a design like Table 1c, row 5 except that in this case, a spring filled with an elastomer hollow is used.

Table 1d, row 5 shows a design similar to Table 1d, row 4 except that a spring filled with an elastomer solid is used.

Table 1e, row 2 shows a variation of the groove in Table 1c, row 5 showing a round bottom groove, using an RF spring. The

advantage of this design is that it provides a concentrated force acting on the spring coil that is desirable in applications where a high stress is needed to remove oxidation of the coil as it turns, thus enhancing electrical conductivity and reducing electrical variability.

Table 1e, row 3 shows a variation of the groove by having a tapered groove that can allow the spring to position in one direction or the other depending on the initial position of the spring during insertion.

Table 1e, row 4 through Table 1f, row 3 shows variations of the design in Table 1b, rows 2-5, and in this case, a tapered bottom groove is used and using a radial spring turned into an axial spring. The tapered bottom groove allows a higher degree of deflection of the spring and allowing a more constant force versus deflection rate than a flat bottom mounted spring.

Table 1f, row 4 shows a variation of Table 1a, row 2 in which a dovetail flat bottom groove is used instead of a flat bottom groove, thus allowing the spring to be retained better in the cavity.

Table 1f, row 5 shows a variation of Table 1f, row 4 by allowing retention of the spring in a different manner than in Figure 25 dovetail design.

Table 1g, row 2 is a variation of Table 1a, row 2 and Table 1c, row 3 in which the tapered and flat bottom is shown.

Table 1g, row 3 shows a variation of the design of Table 1a, row 4 with a slight groove configuration but having the V angles approximately the same.

Table 1g, row 4 shows a variation of Table 1g, row 3 in which the V angles are different so that variations in the angle or angles can be made depending on the application that is intended, thus varying the insertion and running forces.

Table 1g, row 4 through Table 1h, row 3 show additional variations of the groove depending on the intended purpose that is needed for the application.

Table 1h, row 4 through Table 1i, row 4 shows different groove designs to suit a specific need. In this case, however, turn angle springs are being used for the purpose of positioning the spring in such a manner to facilitate assembly and facilitate position of the spring so that it can be favorably positioned in applications where the spring is to be located for other subsequent applications, such as locking, and to vary such connecting forces depending on the intended purpose. The turn angles could be anywhere from 1 to 89 degrees, depending on the application.

Table 1i, row 5 through Table 1j, row 3 shows yet another variation of the groove cavity to retain the spring in place,

depending on the intended application desirable. The running force may be controlled by the angles of the groove walls and the positioning of the spring at assembly.

The various designs indicated in this chart shows an RF spring in preference to an F spring, primarily because of the higher degree of deflection that is available when the front angle is on the outside of the coil. However, the F spring could be used in its place whenever a higher degree of force is desirable with a limited deflection. Also, turn angle springs or different angles may be used ranging from 1 to 89 degrees to suit specific applications.

Piston Mounted Design For Holding And Various Applications (214-28-1).

Tables 2a through 2h shows 37 variations of the manner in which the spring can be mounted in different piston grooves of various designs using different spring configurations to provide variable insertion and running forces. The designs are generally similar to the ones indicated in Tables 1a-1j, whereby the grooves and designs were housing mounted to apply to those applications where a piston mounted design may be desirable.

When mounting the spring into the piston groove - as shown - the back angle of the coil contacts the chamfer of the housing first, upon insertion.

Table 2A, row 2 shows a flat bottom groove with a counterclockwise radial spring.

Table 2a, row 3, column 3 shows a flat bottom groove with a clockwise radially mounted spring with a front angle in a forward direction.

Table 2a, row 2, column 3 shows the general dimensional data for the groove.

Table 2a, row 2, column 4 shows the position of the spring prior to connection and after connection, with the back angle coming in contact with the housing during initial connection.

Table 2a, row 2, column 5 shows the free position of the coil. Table 2a, row 2, column 5 shows a radial spring in a counterclockwise direction.

The forward and backward running force of the pin in the manner indicated will be approximately the same.

Shown in **Table 2a, row 3** is a design like Table 2a, row 2 except that the spring has been turned around 180° and the pin is moving in the same direction as in Table 2a, row 2. Under such conditions, the insertion force will be lower, because the front angle is in the back of the coil, while the running frictional force will be about the same going forward or backwards. In this case, a radial spring in a clockwise direction is shown.

Table 2a, row 4 shows a 'V' bottom groove with a counterclockwise radial spring, which is a variation of the design shown in Table 2a, row 2. The 'V' bottom groove will reduce spring shuttling and enhance electric conductivity. The running force in one direction will be approximately the same as in the opposite direction.

Table 2a, row 5 shows a flat bottom axial groove with axial spring with a pin moving forward in a concave direction. The frictional running force in one direction will be similar to the one in the reverse direction. The groove width is smaller than the coil height, thus retaining the spring firmly in place. A spring as mounted will enhance electrical conductivity due to greater contact area and also reduce electrical variability due to better retention of the spring in the cavity. Shown in this case is a RF axial spring.

Table 2a, row 6 shows a design just like shown in Table 2a, row 5 except that it uses an F type spring with a front angle at the inside of the spring. F type springs produce substantially higher insertion and running forces than RF springs. However, they have lower deflection than RF spring.

Tables 2b, rows 2, 3, 4 and 5 show radial springs mounted in a flat bottom groove with the groove width smaller than the coil height. In these cases, a radial spring that can cant clockwise or counterclockwise has been turned 90° in a clockwise or counterclockwise direction and assembled into a

cavity and retained in such cavity. Under such conditions, the insertion and running forces will be substantially higher. This is done in both RF and F springs.

Table 2b, row 2 shows a flat bottom groove, axial spring with counterclockwise radial spring mounted in an RF position as indicated in Table 2b, row 2, columns 2-6. The force developed when passing a piston groove through a housing with a spring turned from a radial to an axial position will be substantially higher than a comparable RF spring as indicated in Table 2a, row 5 due to the torsional force placed on the spring during insertion into the axial cavity. In this case, a counterclockwise spring is turned 90° into a clockwise axial RF spring and assembled into an axial groove cavity with the groove width smaller than the coil height.

Table 2b, row 3 is like Table 2b, row 2 except that an F spring has been mounted in the cavity. The radial spring turns counterclockwise and is turned 90° to assume an axial counterclockwise spring F type and assembled into the cavity.

Comparison between clockwise radial spring turned 90° into F / RF springs.

Table 2b, row 2, column 6 versus Table 2b, row 3, column 6. Counterclockwise radial spring turned 90° into a clockwise axial RF spring and assembled into a groove with the groove width smaller than the coil height, will yield lower

connecting and running forces compared to the counterclockwise radial spring turned 90° into a counterclockwise axial F spring assembled in the same groove.

The running force in a concave and convex direction will be about the same.

Table 2b, row 4 shows the same design as in Table 2b, rows 2 and 3 except that in this case a radial clockwise spring has been turned into an RF clockwise axial spring by turning it 90°.

Table 2b, row 5 is a design similar to Table 2b, row 4 and in this case the clockwise canting coil spring has been turned 90° into an counterclockwise axial F type spring and assembled into a cavity whose groove width is smaller than the coil height.

Comparison between clockwise radial spring turned 90° into an RF and F axial spring. (See Table 2b, row 4, column 6 versus Table 2b, row 6, column 6). Clockwise radial spring turned 90° into a clockwise axial RF spring and assembled into an axial groove with GW smaller than coil height will yield lower connecting and running forces compared to the clockwise radial spring turned 90° into a counterclockwise axial F spring assembled into the same groove.

Table 2b, row 6 shows a variation of the design indicated in Table 2a, row 5. In this case a 'V' bottom groove is used

that will provide a higher degree of deflection than that can be obtained in Figure 4 and such deflection will be more uniform. Groove width is smaller than the coil height.

Table 2c, row 2 is a variation of Table 2b, row 4 with the groove width larger than the coil height and providing higher deflection but less retention capabilities in the groove.

Table 2c, row 3 shows a 'V' bottom groove with an axial spring with a groove width larger than the coil height. The design is similar to Table 2b, row 6 except that the spring is not retained in the cavity axially, like Table 2b, row 6. In this case, an RF spring is shown but can use a F, radial or angular spring. Groove width can also be larger than the coil height and smaller than the coil width.

Table 2c, row 4 shows a semi-tapered groove with an RF axial spring.

Table 2c, row 5 shows a tapered bottom groove with an RF axial spring.

Table 2a, row 5 through Table 2c, row 5 use axial springs. Such springs can be F or RF or could be radial turned into axial.

Table 2c, row 6 shows a tapered bottom groove with an axial RF spring with a shaft that travels in a convex direction, which is 180° from the one shown in Table 2c, row 5. When the

piston groove travels in a convex direction, the insertion and running forces are substantially higher than when the spring travels in a concave direction and an equivalent description of this feature is also indicated in Figures 16-17. In this case, an RF spring is being used.

Table 2d, row 2 shows a tapered bottom groove with an axial F spring that travels in a convex direction with the groove width smaller than the coil height. The groove configuration is the same as in Table 2c, row 6 except that the spring is an F spring instead of an RF spring. The force in a convex direction is substantially higher than a concave direction and the F spring always provides a higher insertion and running force than an RF spring due to the fact that the back angle is in the OD resulting in substantially lower deflection and higher force.

Table 2d, row 3 is a tapered bottom groove with an RF axial spring filled with an elastomer hollow. This design is similar to Table 2c, row 4 except that the spring is filled with an elastomer hollow.

Table 2d, row 4 is a tapered bottom groove with an RF axial spring filled with an elastomer solid. The design is similar to Table 2c, row 4 except that the spring is filled with an elastomer solid.

Table 2d, row 5 shows a round flat bottom groove with an RF axial spring. This type of design provides a higher stress concentration at one point to scrape oxidation of the spring coil.

Table 2e, row 2 shows an inverted 'V' bottom grove with an RF axial spring that can be moved in a concave or convex direction, depending on the initial movement of the piston groove. In this case, an RF spring is being used.

Table 2e, row 3 through row 6 shows a radial spring turned into an axial spring and inserted in an axial cavity.

Table 2e, row 3 shows a tapered bottom groove with a radial counterclockwise radial spring mounted in RF position with a groove width smaller than the coil height. In this case, a clockwise spring has been turned 90° into an axial RF spring and inserted into the cavity.

Table 2e, row 4 shows a counterclockwise radial spring turned into an axial F counterclockwise spring.

Table 2e, row 5 shows a clockwise radial spring turned into an RF clockwise spring.

Table 2e, row 6 shows a clockwise radial spring turned into axial F spring.

All axial springs can be used in F or RF and radial springs can be turned into axial springs by turning such springs 90° clockwise or counterclockwise and assembling into a cavity whose groove width is smaller than the coil height.

Table 2f, row 2 shows a dovetail groove with clockwise radial spring with a groove width larger than the coil width. The design is similar to Figure 1 except that the spring is better retained in the cavity.

Table 2f, row 3 shows a dovetail groove with clockwise radial spring, which is a variation of Table 2f, row 2.

Table 2f, rows 4-6 and Table 2g, rows 2-4 shows different variations of the groove using a radial spring mounted into such groove. The springs are shown in a counterclockwise mounting direction.

Table 2g, rows 5-6 and Table 2h, rows 2-4 shows variations of different types of grooves using a turn angle spring to achieve specific goals such as to vary the initial insertion force to increase or decrease disconnect force as a subsequent step to enhance conductivity, reduce variability, or enhance areas of contact for better reliability.

Classification of design features and characteristics of holding connectors using the canted coil springs.

Figures 1-37 provide a greater detailed data on the different groove configurations, different types of springs, running forces and background information on the different features of

connectors, force parameters, and unique features of such connectors as related to this patent application.

Figures 1a, 1b, 1c, 1d, and 1e, show a description of the front and back angles of the canted coil spring with the following features.

A canted coil spring consists of two halves. One-half is the shorter back angle half of the coil and the other is the longer front angle half coil. The front angle half is longer (See Figure 1d) and its lever arm is larger (1e), thus less force is needed to deflect such spring compared to the back angle half coil.

Figures 1a, 1b, 1c, 1d, and 1e describe the different positions of a radial spring and the front and back angle.

FIGURE 1

Definitions as apply to this patent application:

(A) *Shaft connecting-insertion force* is the force required to insert the chamfer part of the shaft through the ID of the spring until the ID makes contact with the body of the shaft where the diameter is constant. (See Figures 2c, 3c)

(B) *Housing connecting insertion force* is the force required to insert the piston through the chamfer portion of the housing. (See Table 2a, row 2, columns 2 and 4)

(C) *Running force is the force of the shaft* is the force required to move the body of the shaft (constant diameter part) through the ID of the spring after it has been connected.

(D) *Running force of the piston* is the force required to move the piston through the bore (constant diameter part)

Radial springs. Radial springs are divided into clockwise and counterclockwise springs.

Counterclockwise spring has the front angle in the front. The weld reference point is also in the front angle facing the incoming motion of the shaft. In the case of a housing, the counterclockwise front angle is in the back of the coil (Table 2a, row 2, column 2).

Counterclockwise ***radial*** *spring* is the same as a clockwise radial spring except that it is turned 180°. The running force of a radial spring mounted on a flat bottom groove canting clockwise or counterclockwise is about the same. Counterclockwise radial springs are described in Figure 2a, Figure 2b, and Figure 2c.

FIGURE 2 Counterclockwise radial spring in flat bottom housing groove

Counterclockwise radial springs are described in Figure 2a, Figure 2b, and Figure 2c.

The front angle is in the front facing the incoming motion of the shaft. In the case of the piston (Table 2e, row 3, column 3) the back angle faces the incoming motion of the piston.

The running force developed when the shaft travels against radial springs mounted counterclockwise (Figure 2c), similar to the running force developed when the shaft travels against radial springs mounted clockwise (Figure 3c)

FIGURE 3. Clockwise radial spring and flat bottom housing groove, front angle in the back.

FEATURES

The back angle is in the front, the weld referenced point is in the back facing away from the incoming motion of the shaft or bore. A clockwise radial spring is the same as a counterclockwise radial spring except that it is turned 180°. The running force of a radial spring mounted in a flat bottom housing groove canting clockwise or counterclockwise is about the same.

Figures 3a, 3b, and 3c describe a clockwise radial spring and mounting means in a flat bottom groove.

There is no significant variation in running force when moving the shaft with the spring mounted in a counterclockwise or clockwise position.

Figure 4 shows a RF clockwise axial spring in a tapered bottom groove. The shaft travels forward in a concave position as shown in Figure 4c direction in respect to the ID of the spring.

Figure 5 shows an RF spring clockwise axial spring mounted in a tapered bottom groove, housing groove, shaft travels backward in the convex direction. Direction with respect to the spring ID.

Comparing Figures 4a, 4b, 4c, and 4d with 5a, 5b, 5c, and 5d shows that the running force in a concave direction and the running force in a convex direction is approximately the same.

Figures 6 and 7 shows the same type of design (Figure 6c and Figure 7c) with the spring mounted in a piston. The results are in essence the same, that is, the running force in a concave direction is essentially the same as the convex direction running backwards using an RF spring with the results being similar to those indicated when the spring is mounted in the housing.

Figures 8 and 9 make a comparison similar to those indicated in Figure 4 and 5 but in this case an F axial spring is being used. The results show that when an F spring is mounted in a housing and the concave and convex direction is measured, going forward and back, the convex direction develops approximately 7% greater force than the concave direction, indicating that the F springs with lower deflection and higher force per unit deflection develops a higher differential running force than an equivalent RF spring by approximately 18% to 25%.

Figures 10 and 11 shows an F spring mounted in a piston and the results also indicate that when a F spring is mounted in a piston and moved forward in a concave direction, it develops

lower force than when moving the same piston backwards in a convex direction. The variation is approximately 7% with a convex movement developing higher force.

Figure 12. Counterclockwise radial spring turned 90° counterclockwise into a counterclockwise axial F spring and assembled in a groove with groove width smaller than the coil height. This is described in Figures 12a through 12g. Comparing an axial spring as indicated in Figures 8a, 8b, and 8c and compared to that of 12a through 12g shows that when a radial spring has been turned 90° into an axial spring and assembled into a groove, the coils have higher stress level compared to an axial F spring in the same groove. This added stress develops higher running force.

Another factor that affects running force is when the shaft travels in a concave direction. The friction between the shaft and spring turns the spring clockwise, opposing the natural tendency of the spring as its torsional force tries to return the spring to its built-in radial position by turning counterclockwise. The combination of pre-stress torsional force direction and position of the back angle at the OD gives this design 12-c about 10 to 30 percent higher running force compared to the design in Figure 8c.

Figure 13. Counterclockwise radial spring turned 90° clockwise into a clockwise axial RF spring assembled in a groove with a groove width smaller than the coil height.

Figures 13a through 13g describe this spring. It has been turned from a radial counterclockwise spring into an axial RF

spring. Comparing 13g to 4c it shows that when a radial spring has been turned 90° into an axial spring and assembled into a groove, the coils have a higher stress level compared to an axial RF spring in the same groove. This added stress develops higher running force. Another factor that affects the running force is when the shaft travels in a concave direction. The friction between the shaft and spring turns the spring clockwise, assisting the natural tendency of the spring as its torsional force tries to return the spring to its built-in radial position by turning clockwise. The combination of pre-stress torsional force direction and position of the back angle at the ID gives the design 13c about 10 to 20 percent higher running force compared to the design in Figure 4c.

Figure 14. Clockwise radial spring turned 90° counterclockwise into a clockwise axial RF spring and assembled in a groove with a groove width smaller than the coil height. Comparing Figures 14g with 4c it shows that the combination of pre-stress torsional force and position of the back angle at the ID gives this design 14g about 10 to 20 percent higher running force compared to the design in 4c.

Figure 15 clockwise radial spring turned 90° clockwise into a counterclockwise axial F spring and assembled in a groove with groove width smaller than the coil height. Figures 15a through 15g describe this type of spring and when we compare Figure 15g to 8c it shows that the combination of pre-stress torsional force direction and position of the back angle at

the OD gives this design (Figure 15c) about 10 to 30 percent higher running force compared to the design in Figure 8c.

Figure 16 and Figure 17.

Figure 16. Axial RF and F springs show a shaft moving in the concave direction of the spring ID as shown in Figures 16a and Figure 16b and Figure 17 showing an axial RF and F spring shaft moves in the convex direction of the spring ID as shown in Figure 17a and Figure 17b. In this case, a comparison has been made between the direction of motion in a concave direction as indicated in Figure 16a and 16b with that of Figure 17a and 17b. The results show that for both RF and F springs when the pin or shaft moves in a concave direction it provides substantially lower force than when the same pin is turned around 180° and move the pin in a convex direction with the RF springs developing substantially lower force than the F springs. See Table 3 for results and Table 4 for spring/groove specifications.

The unexpected results show as follows:

RF spring. Running Force. The running force of the shaft traveling in the convex direction is 304% higher than the running force of the shaft traveling in the concave direction.

F spring. Running Force: The running force of the shaft traveling in the convex direction is 1233% higher than the running force of the shaft traveling in the concave direction.

Conclusion:

The running force difference between the shaft traveling in the concave and convex direction is substantial. When the shaft travels in the convex direction, the insertion and running forces are higher in both RF and F axial springs. In RF springs the increase in running force was 304%. In F spring the increase was 1233%.

The substantially higher force when the shaft is inserted and traveled in the convex direction occurs because during insertion, the shaft's chamfer turns the spring clockwise, as the spring turns clockwise, the point of contact between the shaft and the spring moves closer to the centerline of the major axis where no spring deflection is possible. Large amount of force is required to force the chamfer part of the shaft to pass the spring. After the shaft has been inserted and the spring has wedged against the shaft, the shaft continues to travel in the same direction, the friction between the spring and the shaft turns the spring clockwise opposing the natural tendency of the spring as it tries to deflect. The action keeps the spring in the wedged position and therefore a large amount of force is required for the shaft to travel in the convex position after it has been inserted in the same direction (Fig. 17a and Fig. 17b).

The 'F' springs in the convex direction produces substantially higher running force 1233% than 'F' springs in the concave direction. In 'RF' springs, the running force in the convex direction is 304% higher than in the concave direction.

Values vary depending on various parameters such as groove dimensions, spring dimensions and piston/shaft dimensions, etc.

Figures 18 and 19. Reviewing Figures 18 and 19 when the pin moves away from a turn angle 'a' the running force developed is substantially less than when the pin moves towards the tapered angle 'a'. In both cases, the spring turns clockwise.

Figures 20 and 21. Radial springs. OD of radial spring is larger than the ID of the housing spring mounted in the housing. This is described in Figures 20a, 20b, and 20c in which it shows that the OD of the spring is larger than the ID of the cavity in which such spring is to fit. Compressing the spring from the OD results in an increase in the back and front angles of the coil and thus reducing the insertion and running forces.

Figure 21 radial spring. OD of radial spring is the same as the OD of the housing spring mounted in the housing.

Figures 21a, 21b, and 21c shows that the ID of the spring is smaller than the shaft diameter, thus requiring stretching of the spring. In stretching the spring from the ID results in a decrease in the front and back angle, resulting in higher insertion and running frictional forces.

Table 5 makes a comparison between springs having different springs ID and OD and assembled into the same cavity having the same shaft and same housing. The results shows that the stretching the spring from the ID results in higher running

force. Compressing the spring from the OD results in lower running force.

Figure 22. Radial spring. Spring mounted on the piston, spring ID is smaller than the piston groove diameter indicated in Figures 22a and 22b. In this case, by stretching the spring to mount in a groove or piston results in higher running force.

Figure 23. Radial spring. Spring mounted on the piston. Spring ID is equal to the piston groove diameter.

Figure 23a, Figure 23b, and Figure 23c. In this case, the spring ID is equal to the piston groove diameter but the spring OD is larger than the housing diameter. The results show that by compressing the coils from the OD of the spring it increases the front and back angles, resulting in lower breakout and running forces.

Figure 24. Same shaft diameter, same spring diameter, varying housing bore diameter. This is indicated in Figure 24 in which it shows an assembly with the same shaft diameter and the same spring with different housing diameters. Compressing the spring coils from the OD results in lower running frictional forces than compressing the coils from the ID. The reason being is that when compressing the coil from the OD it increases the front and back angle, decreasing the force required to pass a plunger through such spring ID.

Figure 25. Same housing bore diameter, same spring diameter, bearing shaft diameter. Figure 25 shows an assembly having a constant bore diameter, a constant spring diameter, and a

variable shaft diameter. The results, as indicated, in Table 6 comparing the running force of a spring compressed from the OD at various deflections shows that compressing the coils from the OD while maintaining the same spring and shaft diameter results in lower running force.

Table 7 compares running force of a spring compressed from the ID at various deflections and it shows that stretching the spring ID to the shaft diameter and compressing the coils from the ID results in higher running force. Stretching the spring increases the deflection before butting.

Figure 26. F spring vs. RF spring mounted in a housing. Figure 26a and Figure 26b makes a comparison between an RF spring mounted in the same housing versus an F spring mounted in the same housing. The RF spring has the front angle on the OD while the F spring has a front angle at the ID. The results, as indicated in Table 8 shows that RF springs develop 10 to 20 percent lower running force than F springs under the same conditions.

The results show then that an F series spring develops higher running force than RF series. The average running force of the RF springs is 10% to 20% lower compared to the average running force of the F spring, depending on the spring series. Table 8 compares the running force of F springs mounted in a housing. RF springs develop 10 to 20 percent lower running force than F springs under the same conditions. Table 8 shows a variation of approximately 10% lower for the RF springs. Values vary substantially with the spring and groove parameters.

Figure 27. F spring versus RF spring mounted on a piston

Figure 27a shows a RF spring mounted on a tapered bottom piston with the front angle at the OD and the back angle at the ID.

Figure 27b shows the same type of design except that in this case, an F spring is shown with the front angle at the ID and the back angle at the OD. The spring is assembled in the cavity having a groove width smaller than the coil height and assuming a vertical position. Upon assembling the piston into the housing, the spring assumes a concave position, and the running force of the RF spring is lower than the force of the F spring, changing from approximately 10% to 30% lower. Table 9 shows a variation of approximately 16% lower for the RF springs. Values vary substantially with the spring and groove parameters.

Figure 28 shows a variation of the RF spring diameter and its effect on forces.

Figure 28a shows axial springs of different diameters with the smaller diameter equal to the shaft diameter. Other springs having a larger ID when assembled into the housing whose groove width is smaller than the coil height. Upon assembling such springs into the same cavity, as indicated in Figure 28c, the spring coils assume a position as indicated in Figure 28f, and the springs having a larger inside diameter

and a larger outside diameter and therefore more coils per spring, when compressed radially by reducing the outside diameter, causes the back angle and front angle to increase, decreasing the force required to pass a plunger through the ID of such spring. The results, as indicated in Table 10 *Axial RF Spring Versus Running Force*, show that the larger diameter springs with more coils develop lower force than the springs with fewer number of coils and having a smaller inside and outside diameter. The variation can range anywhere from 10 to 30 percent or more depending on spring and groove parameter.

Figure 29 compares the variation of an F spring diameter and its effect on force.

Figure 29a, 29b, and 29c are the same as in Figure 28, except that an F spring instead of an RF spring is being used; the F spring having the front angle at the ID and the back angle at the OD. The results, as indicated in Table 11, show that the springs with the larger outside diameter and thus a larger number of coils when compressed into a housing, as indicated in Figure 29b, show that the larger diameter springs when the pin is passed through the ID of such spring develop a substantially lower force than the smaller diameter springs, as indicated in Table 11. The variation ranges from approximately 10 to 30 percent and such variations depend on groove and spring considerations.

Comparing the running forces between the RF and F springs indicated in Figures 28b and 29b as recorded in Table 10 and 11, it shows that F springs under the same conditions develop higher running forces than RF springs.

Figures 30 to 37 shows different kinds of groove spring configurations having a flat bottom groove, both on the housing and in the piston using axial springs in a groove whose groove width is smaller than the coil height.

Figure 30 and 31 makes a comparison between the force developed when passing a pin in a concave and a convex direction. In this case, when using an RF spring, the running force back and forth is essentially the same in both cases.

Figure 32 and 33 shows design where the spring is mounted in a piston groove with the front angle on the OD and the back angle on the ID. In this case, the springs are also positioned in a concave position and when moving the pin in a concave direction or in a convex direction, the running force is essentially the same in one direction or the other.

Figure 34 and 35 shows an F spring mounted in a housing and the pin moving in a concave direction and also in a convex direction. In this case, when the pin is moved in a convex direction, the running force with the F type spring runs approximately 10 to 30 percent higher than when running in a concave direction. The variation depends on the groove configuration and spring design.

Figure 36 and 37 also makes a comparison between a F spring mounted in a piston groove and the pin moving in a concave or convex direction. When the pin is moved in a convex direction, the frictional force developed is anywhere from 10 to 30 percent higher than when moving in a concave direction.

A review of the results indicated in Figures 30 to 37 indicates that when using the RF spring, having a front angle on the OD and the back angle on the ID, the force versus deflection remains much more constant than when using an F spring that has substantially lower deflection and a higher force versus deflection; thus, a small amount of deflection results in a substantially higher force and is represented by the values indicated, whereby when using the F spring the insertion and running forces are substantially higher than those obtained with an RF spring.

The springs herein shown illustrate circular springs that can radial, axial or turn angle, that can be joined in various ways, primarily by bringing the ends together by welding, thus forming a circle. However, such springs can also be held together in many other ways and still permit the operational requirements as indicated.

The springs can be mounted in a housing groove or can be mounted in a piston groove and the springs can be radial and mounted radially; can be radial and mounted axially and can be axial and mounted axially and the springs can also be turn angle and they can be mounted radially or axially.

<u>Housing mounted springs</u>. The housing mounted springs can be assembled into a groove in the following manner.

1. By making the length of the spring longer than the length of the circumference that the groove in which it is to fit so that the ends of the spring can be encased

into the ends of such coils in a radial, axial or turn angle manner.

2. By making the length of the spring slightly longer than the length of the circumference of the groove so that upon assembling into the housing the ends of the spring will come in contact with each other, due to the longer length of the spring over the length of the cavity.

3. By making the length of the spring shorter than the length of the circumference of the groove in which it is to fit in so that upon assembly there will be a gap between the ends of the coils, once assembled into the cavity.

Piston mounted springs. The piston mounted springs will be made in a similar manner as the ones that are mounted in the housing as follows:

1. Making the length of the spring larger than the internal groove length of the cavity so that the ends of the coils are encased into each other, be radial or axial or turn angle.
2. By making the length of the spring slightly larger than the length of the circumference of the piston groove so that upon assembly, the ends of the coil will be butting against each other.
3. By making the length of the spring smaller than the length of the circumference of the piston groove so that upon assembly there will be a gap between the coils.

The springs can be radial and upon assembly, they can cant clockwise or counterclockwise. The springs can also be axial whereby upon assembly they will be RF with a front angle on the OD or F with the front angle on the ID.

The length of the springs can be assembled in the housing or in the piston as indicated in US patent 5,709,371, US patent 5,791,638 and US patent 5,615,870 all to Bal Seal.

The conductivity/resistivity and the variability of the current passing from the housing to the shaft through the spring or vice versa is affected by various parameters, which are as follows:

The method of mounting the spring in the housing, be it a radial or axial spring. An axial spring or a radial spring mounted axially will develop higher stress on the shaft than an equivalent radial spring.

An F spring will develop a higher stress on the shaft than an equivalent RF spring.

The smaller the ratio of the spring ID to the coil height, the higher the stress acting on the coils at the ID and the higher the stress acting on the shaft.

The smaller the ratio of the spring ID to the ratio of the coil height to wire diameter, the higher the stress acting on the coils at the ID and the higher the stress acting on the shaft. The resistivity and conductivity is affected to a certain extent by the stress in pounds per square inch acting

on the shaft. Such stress is not linear, meaning that after a certain amount of stress an increase in stress does not result in an increase in conductivity. However, the variability of the resistivity is reduced by higher stress acting on the shaft. The higher the eccentricity and angular misalignment, the higher the variability that can occur. Therefore, the most desirable condition occurs when we obtain maximum deflection of the spring coils as well as adequate stress of those coils. The higher deflection of the spring at the ID of such spring will permit a higher degree of eccentricity, angular misalignment, and tolerance variation of the pin. For example, Table 1a, row 2, column 2, 3 and 4, show a radial spring mounted in a housing and developing a minimum amount of stress acting on the shaft, but a high degree of deflection of the coil. On the other hand, row 5, column 2, uses an axial spring with a flat bottom groove that develops a high level of stress on the pin but a lower ability to accommodate eccentricities, misalignment and tolerances than Table 1a, row 2, columns 2, 3, and 4.

On the other hand, row 5, column 2 and 3 of Table 1a, with an axial spring having a tapered bottom groove provides slightly lower stress than row 5, column 2, row 6, column 2 of Table 1a, but a higher degree of deflection at the coil ID that can accommodate better tolerance variations, eccentricities and angular misalignment of the coil, thus affecting electrical resistivity. In addition, the type of axial spring being an RF or F affects the stress acting on the pin as well as ability to accommodate eccentricities,

tolerance variations, and angular misalignment of the pin. The RF spring provides lower stress but a greater ability to accommodate for tolerances, misalignment and eccentricity. These variations affect the selection of the spring, either radial or axial and the type of radial spring and the type of groove design. It has been discovered that for most general applications where resistivity and resistivity variability is to be kept at a minimum, the design indicated in Figure 14A Chart I, with the tapered bottom groove having a front angle on the OD offers the best combination of properties in holding applications. Whenever a high degree of stress is indicated with limited radial variation, the design indicated in row 5, Table 1a, combines such properties. The designs indicated in rows 2, 3 and 4 of Table 1a, provide limited stress on the pin but the force variability during axial movement of the pin is substantially more constant.

Although there has been hereinabove described specific spring holding connectors in accordance with the present invention for the purpose of illustrating the manner in which the invention may be used to advantage, it should be appreciated that the invention is not limited thereto. That is, the present invention may suitably comprise, consist of, or consist essentially of the recited elements. Further, the invention illustratively disclosed herein suitably may be practiced in the absence of any element which is not specifically disclosed herein. Accordingly, any and all modifications, variations or equivalent arrangements which may occur to those skilled in the art, should be considered to be

within the scope of the present invention as defined in the appended claims.

TABLE 1a

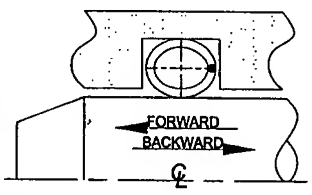
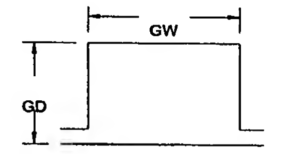
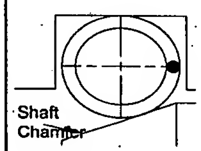
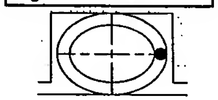
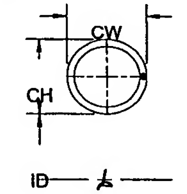
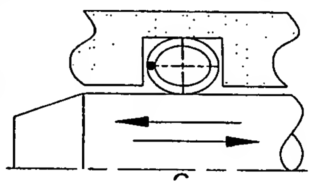
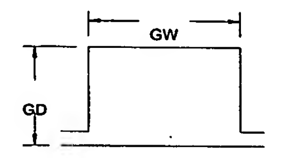
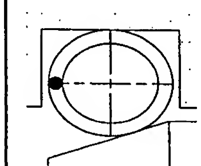
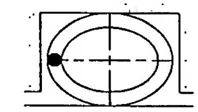
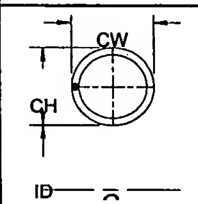
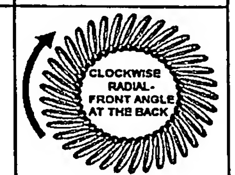
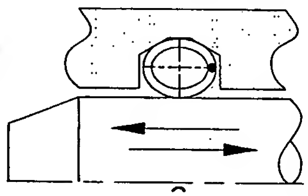
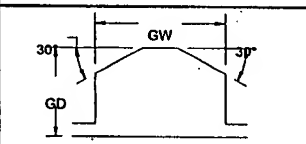
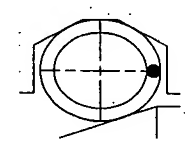
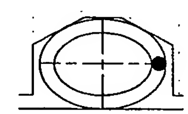
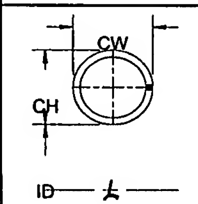
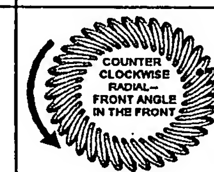
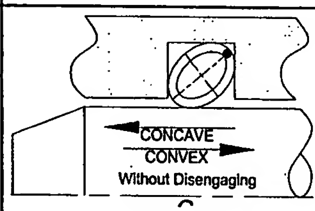
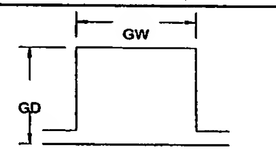
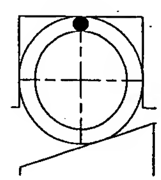
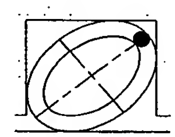
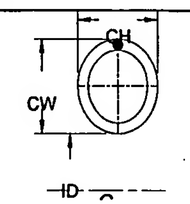
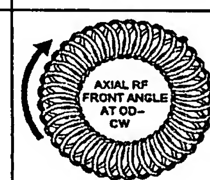
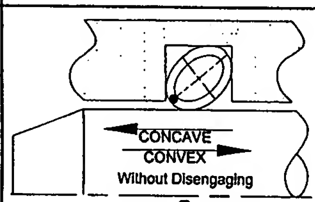
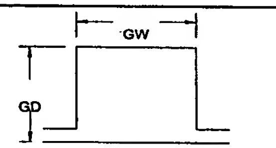
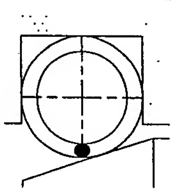
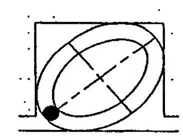
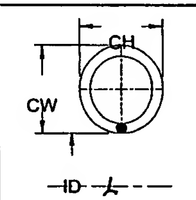
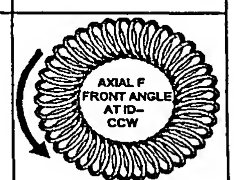
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Flat-Bottom Groove with Counter-clockwise Radial Spring GW>CW				Upon insertion, the front angle of the coil contacts 		
Flat-Bottom Groove with Clockwise Radial Spring GW>CW						
V-Bottom Groove with Counter-clockwise Radial Spring GW>CW						
Flat-Bottom-Axial Groove with RF Axial Spring GW<CH						
Flat-Bottom-Axial Groove with F Axial Spring GW<CH						

TABLE 1b

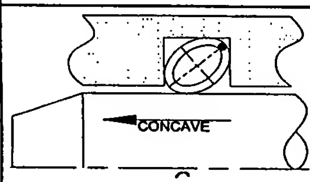
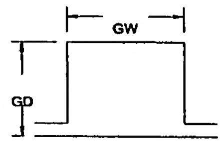
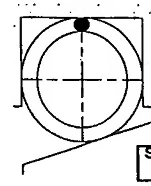
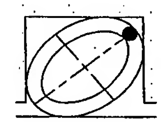
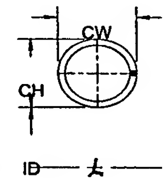
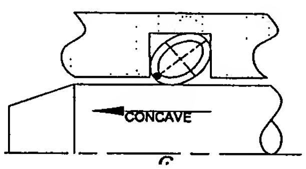
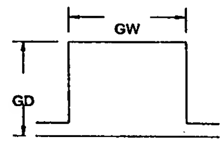
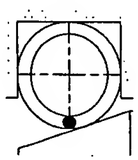
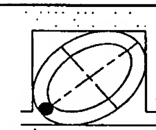
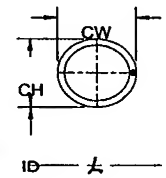
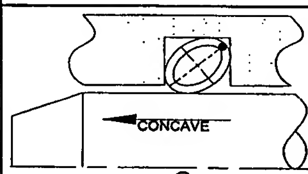
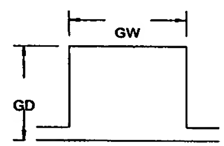
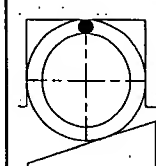
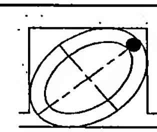
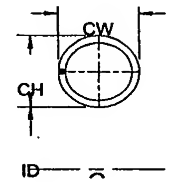
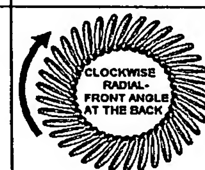
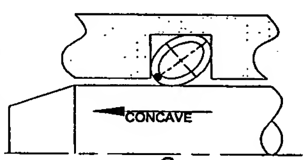
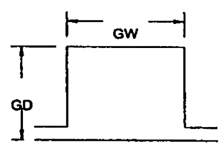
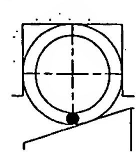
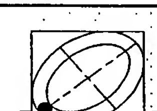
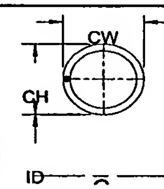
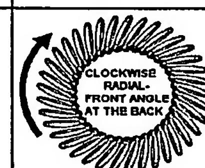
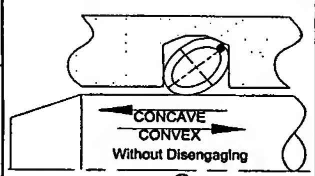
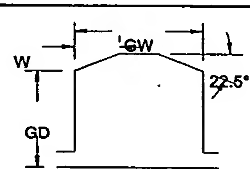
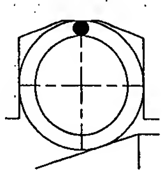
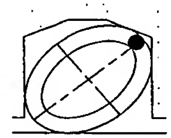
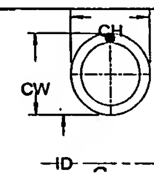
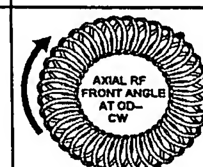
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Flat-Bottom Axial Groove with Counter Clockwise Radial Spring Mounted In RF Position GW<CH				 Spring assembled in an RF position		
Flat-Bottom Axial Groove with Counter Clockwise Radial Spring Mounted in F Position GW<CH				 Spring assembled in an F position		
Flat-Bottom Axial Groove with Clockwise Radial Spring Mounted in RF Position GW<CH				 Spring assembled in an RF position		
Flat-Bottom Axial Groove with Clockwise Radial Spring Mounted In F Position GW<CH				 Spring assembled in an F position		
V-Bottom Groove with RF Axial Spring GW<CH						

TABLE 1c

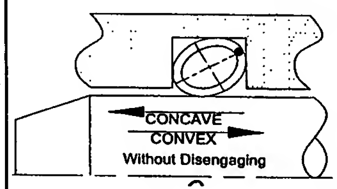
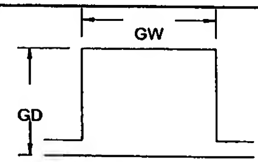
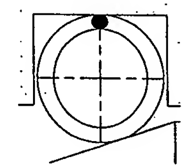
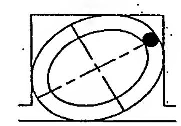
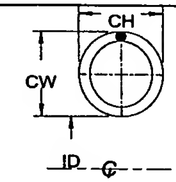
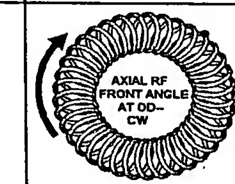
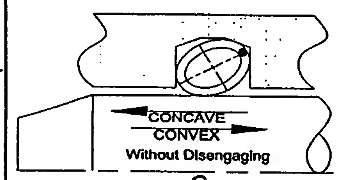
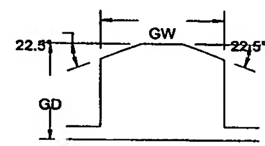
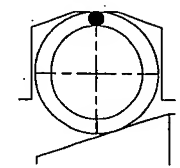
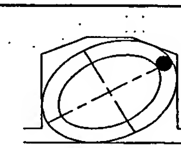
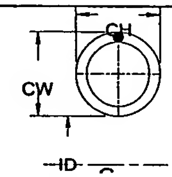
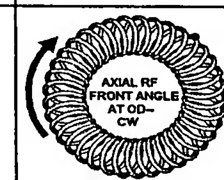
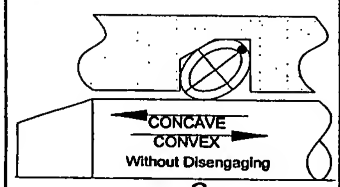
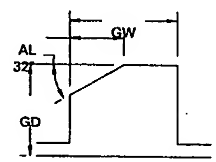
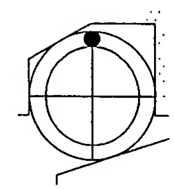
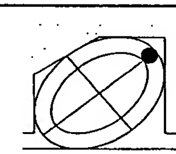
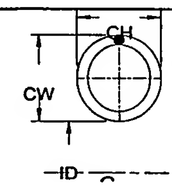
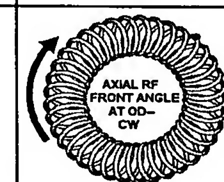
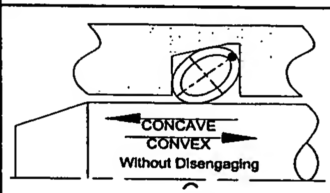
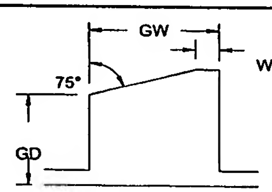
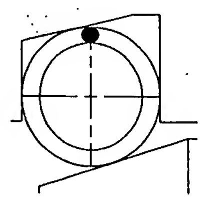
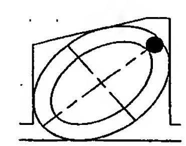
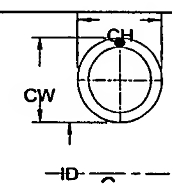
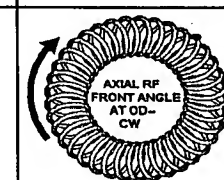
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Flat-Bottom Groove with RF Axial Spring GW>CH						
V-Bottom-Tapered Groove with RF Axial Spring GW>CH						
Semi-Tapered Groove with RF Axial Spring GW<CH						
Tapered-Bottom Groove with RF Axial Spring GW<CH						

TABLE 1d

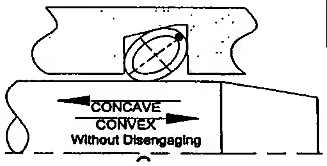
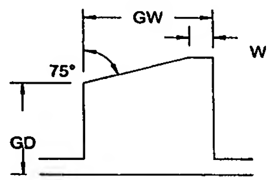
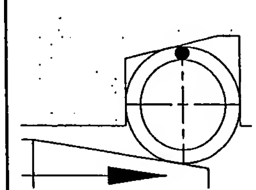
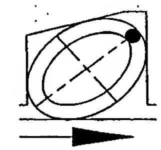
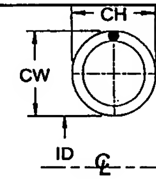
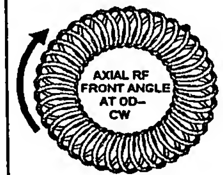
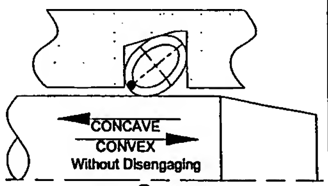
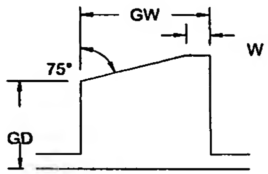
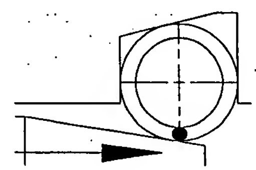
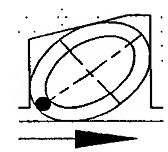
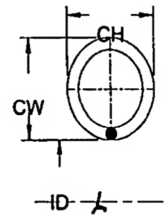
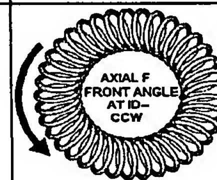
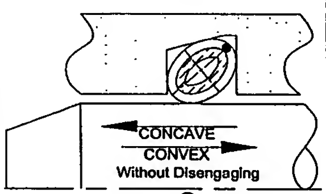
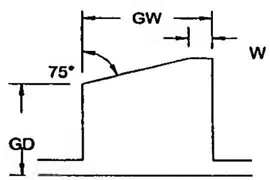
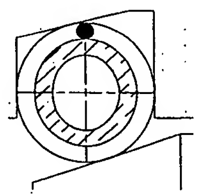
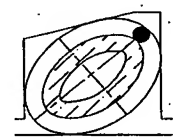
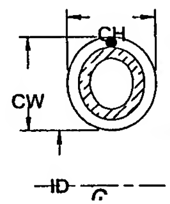
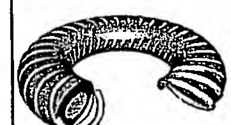
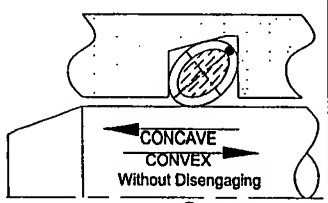
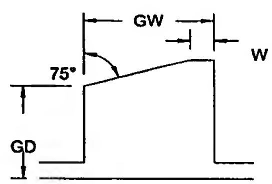
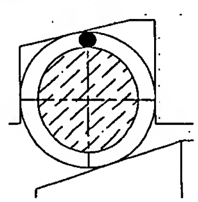
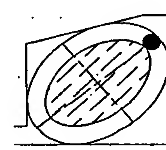
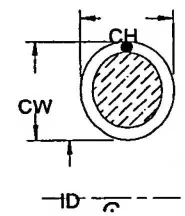
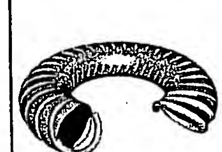
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Tapered-Bottom Groove with RF Axial Spring–Shaft Travels in the Convex Direction GW<CH						
Tapered-Bottom Groove with F Axial Spring–Shaft Travels in the Convex Direction GW<CH						
Tapered-Bottom Groove with RF Axial Spring Filled with Elastomer (Hollowed) GW<CH						
Tapered-Bottom Groove with RF Axial Spring Filled with Elastomer (Solid) GW<CH						

TABLE 1

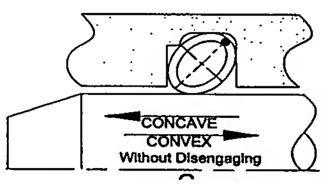
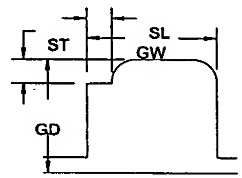
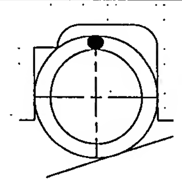
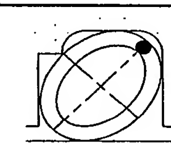
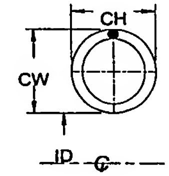
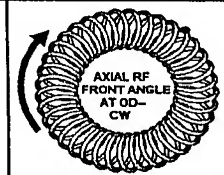
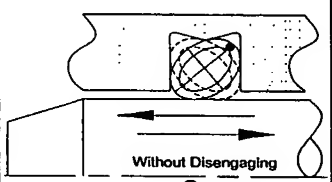
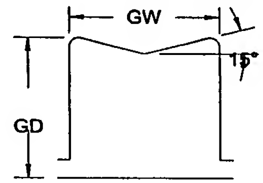
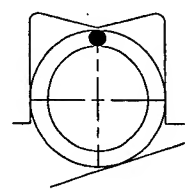
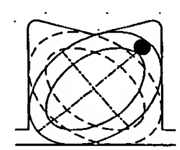
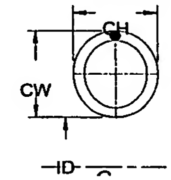
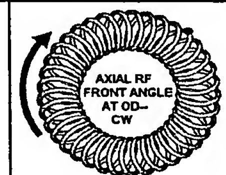
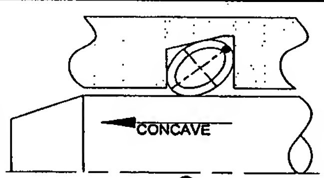
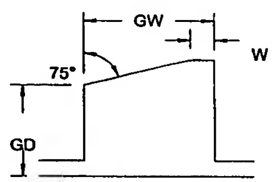
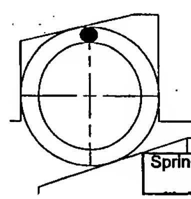
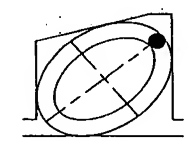
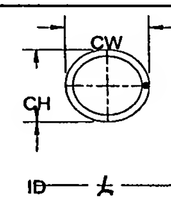
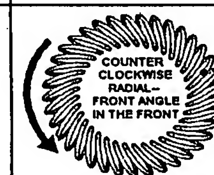
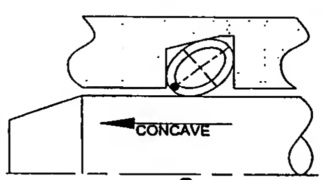
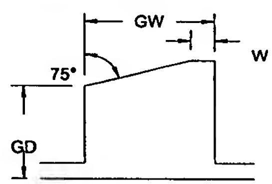
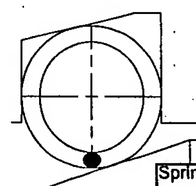
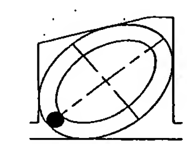
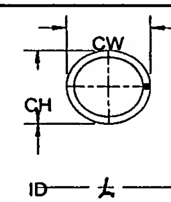
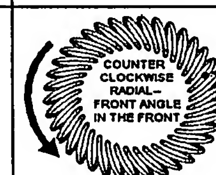
Types of Grooves- Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Round-Bottom Groove with RF Axial Spring GW<CH						
Inverted-V-Bottom Groove with RF Axial Spring GW<CH						
Tapered-Bottom Groove with Counter Clockwise Radial Spring Mounted in RF Position GW<CH						
Tapered-Bottom Groove with Counter Clockwise Radial Spring Mounted in F Position GW<CH						

TABLE 1f

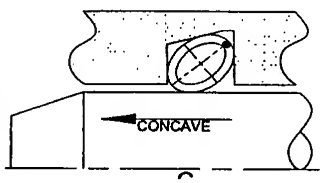
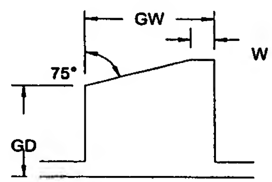
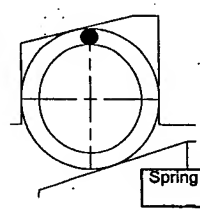
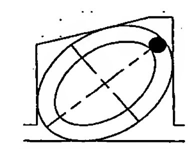
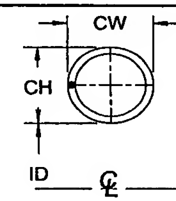
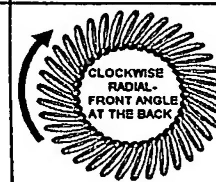
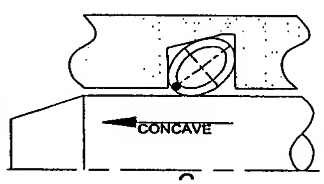
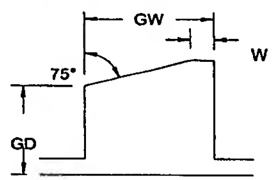
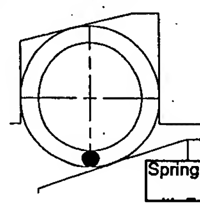
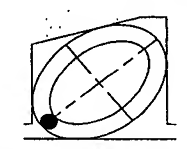
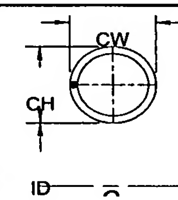
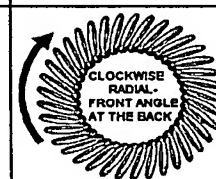
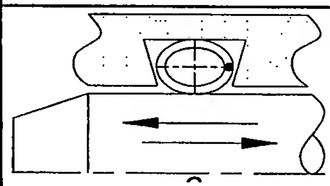
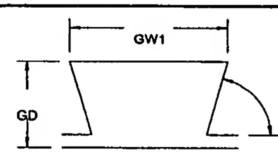
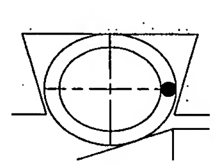
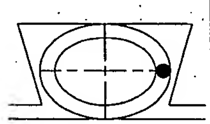
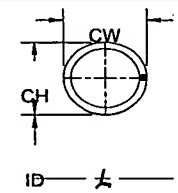
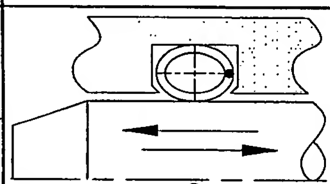
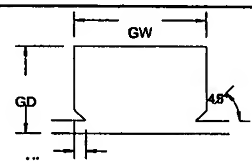
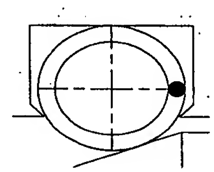
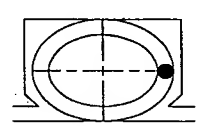
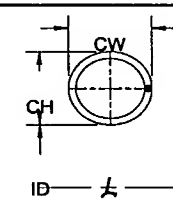
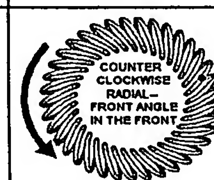
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Tapered-Bottom Groove with Clockwise Radial Spring Mounted in RF Position GW<CH				 Spring assembled in an RF position		
Tapered-Bottom Groove with Clockwise Radial Spring Mounted in F Position GW<CH				 Spring assembled in an F position		
Dovetail Groove with Counter-clockwise Radial Spring GW>CW						
Dovetail Groove with Counter-clockwise Radial Spring GW>CW						

TABLE 1g

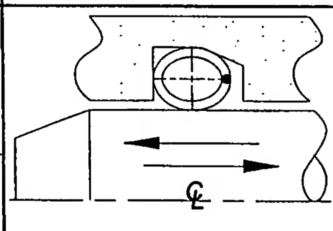
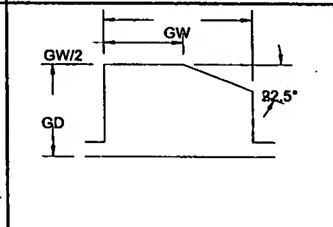
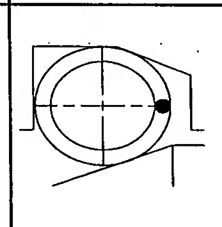
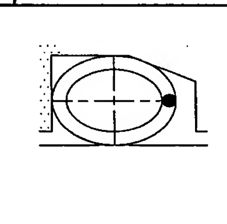
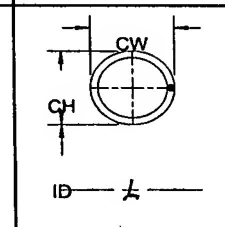
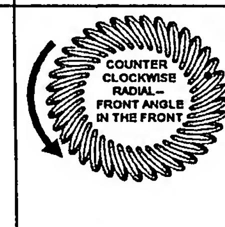
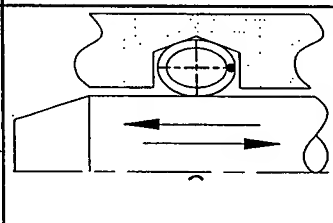
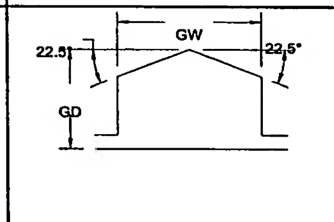
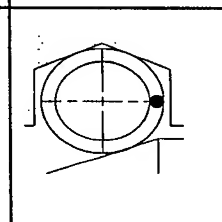
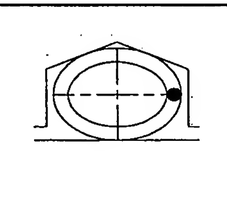
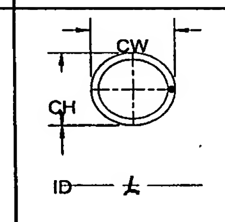
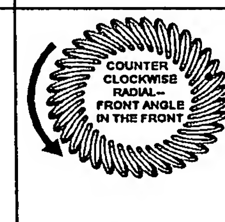
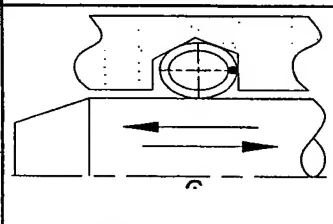
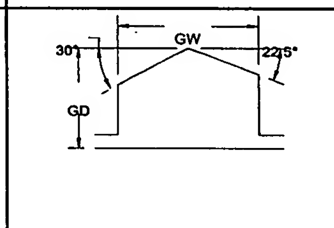
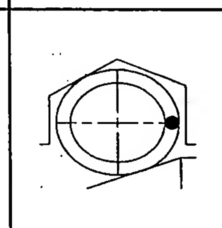
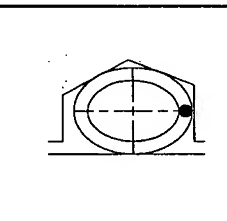
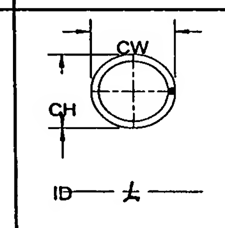
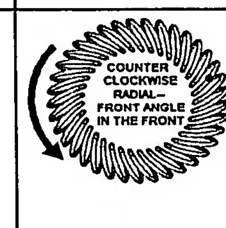
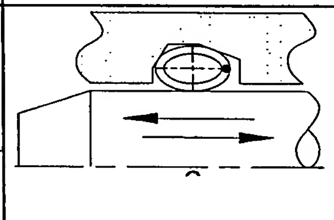
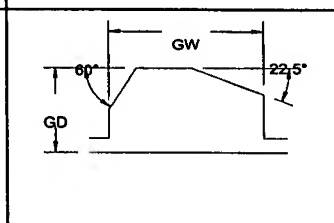
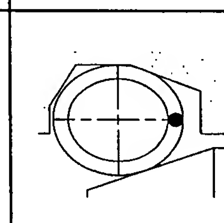
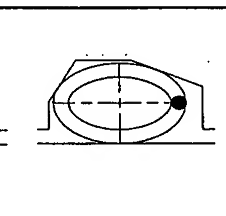
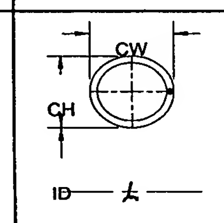
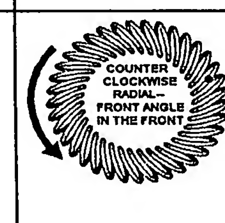
Types of Grooves- Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Angle 0°-22.5°-Bottom Groove with Counter-clockwise Radial Spring GW>CW						
Angle 22.5°-22.5°- Bottom Groove with Counter-clockwise Radial Spring GW>CW						
Angle 30.0°-22.5°- Bottom Groove with Counter-clockwise Radial Spring GW>CW						
Angle 60.0°-22.5°- Bottom Groove with Counter-clockwise Radial Spring GW>CW						

TABLE 1h

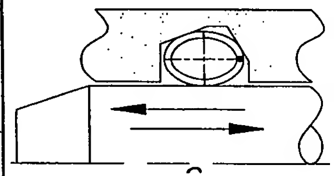
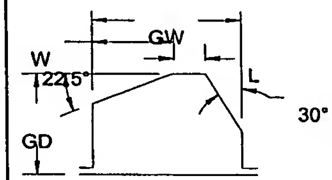
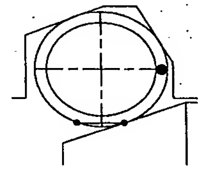
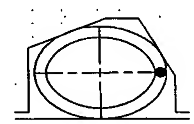
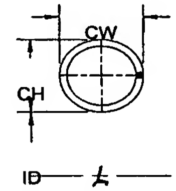
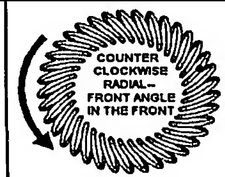
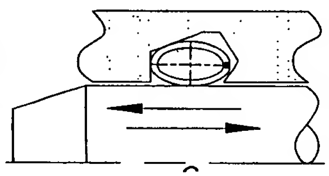
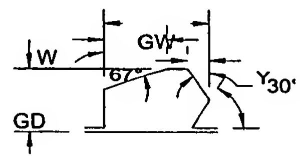
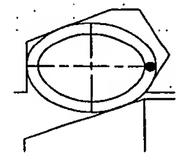
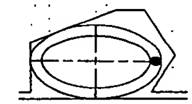
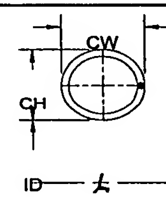
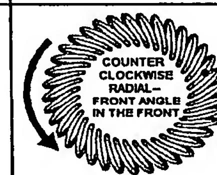
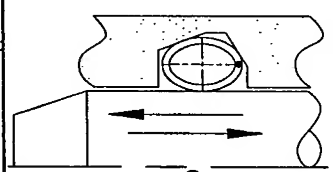
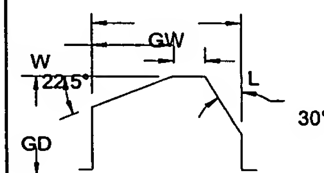
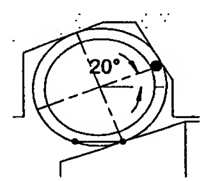
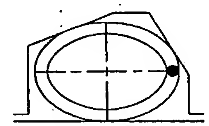
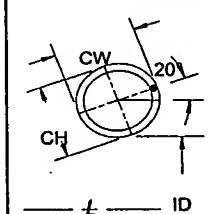
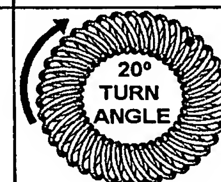
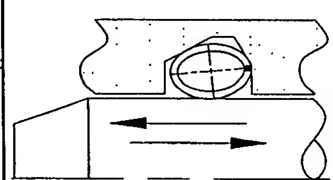
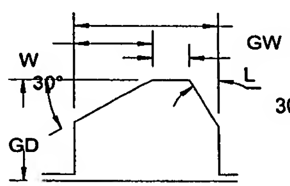
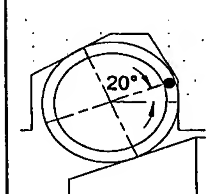
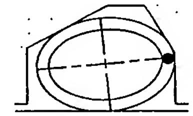
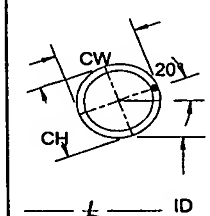
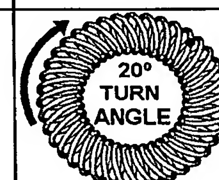
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Special V Bottom with 22.5° and 30° Angles Groove with Counter-clockwise Radial Spring GW>CW						
Special-V-Bottom-with-67°-30°-60°-Angles Groove with Radial Spring GW>CW						
Special-V-Bottom-with-22.5°-and-30°-Angles Groove with 20° turn angle spring GW > CW						
Special-V-Bottom-with-30°-and-30°-Angles Groove with 30° turn angle spring GW > CW						

TABLE 1i

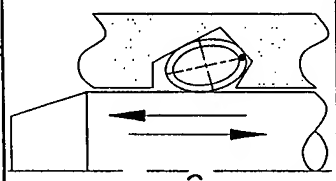
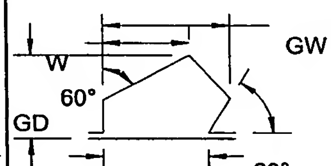
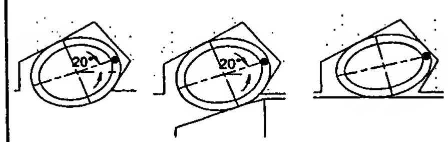
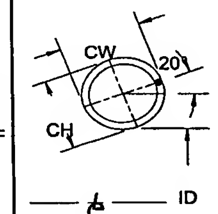
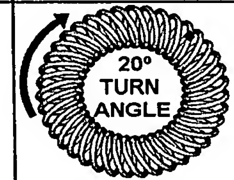
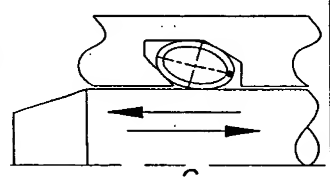
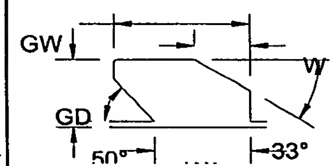
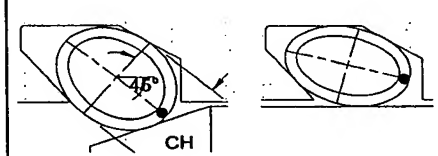
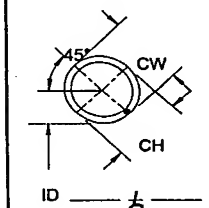
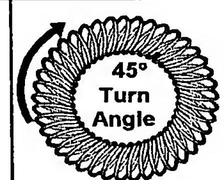
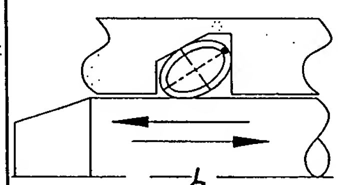
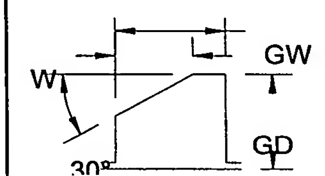
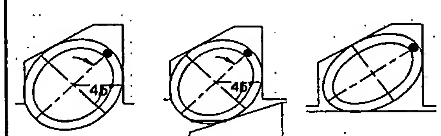
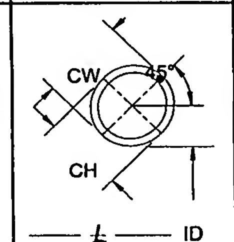
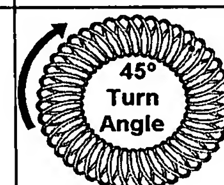
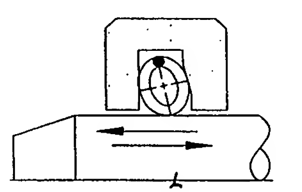
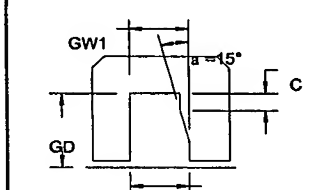
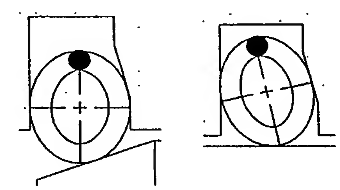
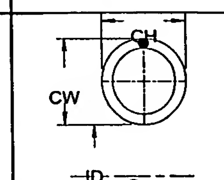
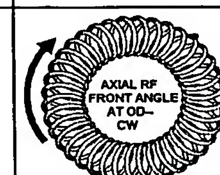
Types of Grooves- Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Special-V-Bottom-with-60°-and-60°-Angles Groove with 20° turn angle spring GW > CW						
Special Groove with 45° turn angle spring GW>CW						
Special-Tapered-Bottom-with 30°-Angle Groove with 45° turn angle spring GW<CW						
Side Loaded Angular Groove with Axial Spring GW<CH						

TABLE 1j

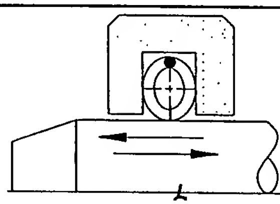
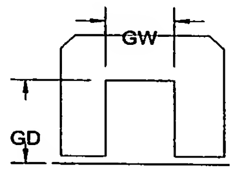
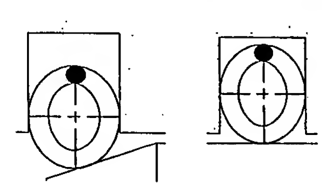
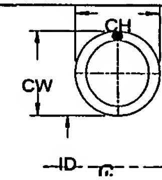
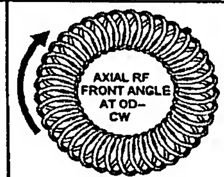
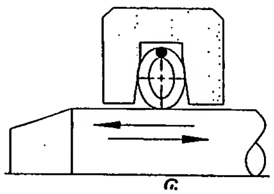
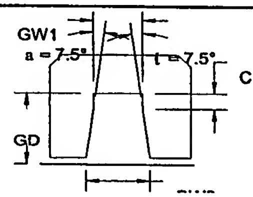
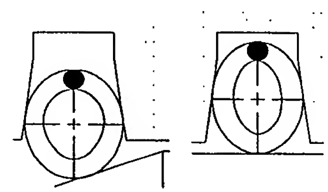
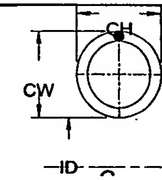
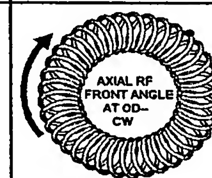
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Side-Loaded-No-Angle Groove with Axial Spring GW<CH						
Side-Loaded-Symmetrical-Angles Groove with Axial Spring GW<CH						

TABLE 2a

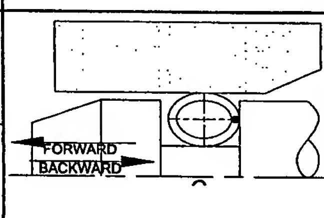
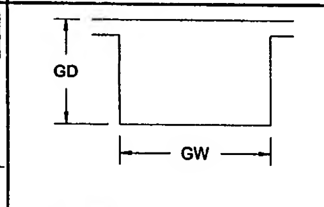
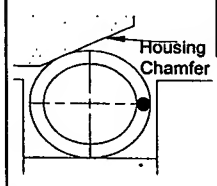
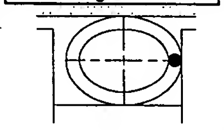
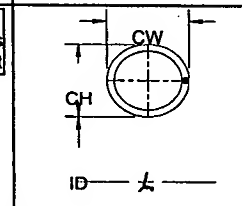
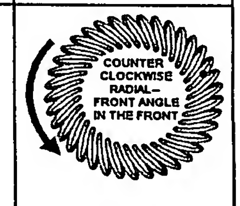
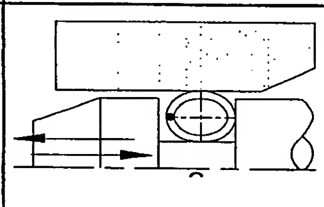
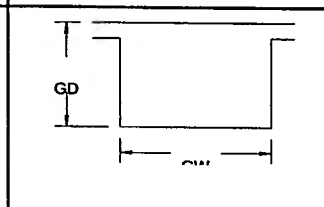
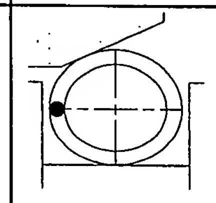
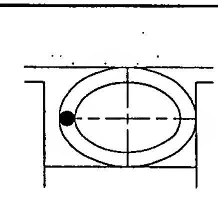
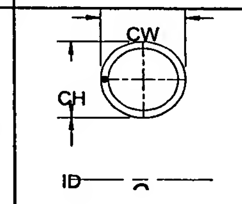
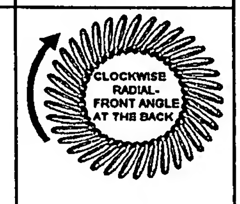
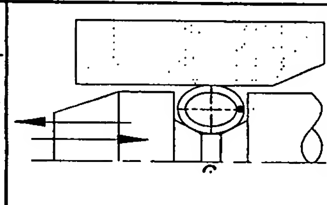
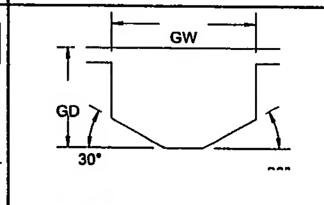
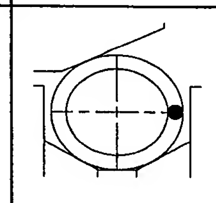
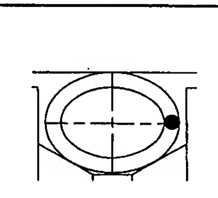
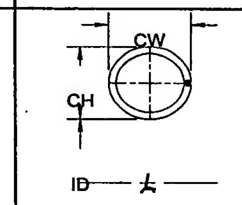
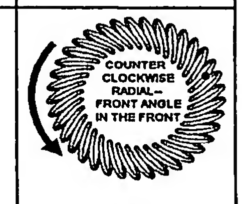
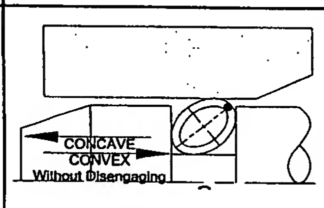
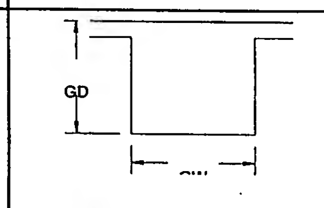
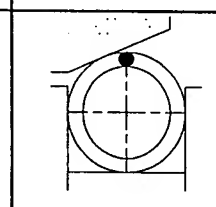
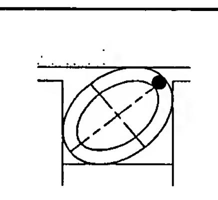
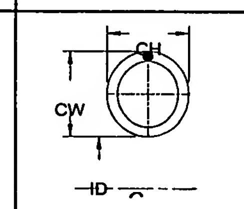
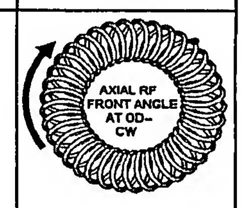
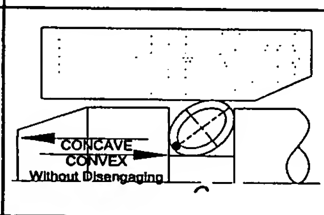
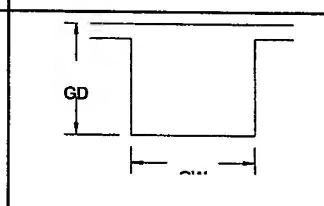
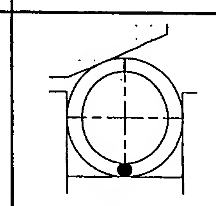
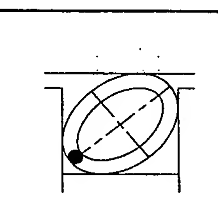
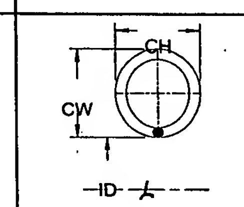
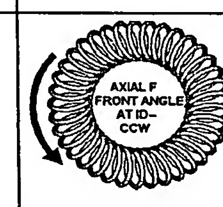
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Flat-Bottom Groove with Counter-clockwise Radial Spring GW>CW				Upon insertion, the back angle of the coil contacts the housing chamfer first 		
Flat-Bottom Groove with Clockwise Radial Spring GW>CW						
V-Bottom Groove with Counter-clockwise Radial Spring GW>CW						
Flat-Bottom-Axial Groove with RF Axial Spring GW<CH						
Flat-Bottom-Axial Groove with F Axial Spring GW<CH						

TABLE 2b

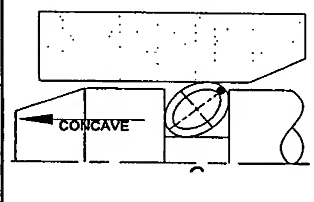
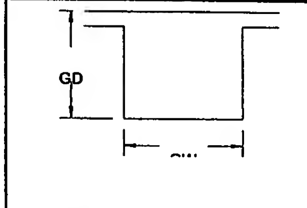
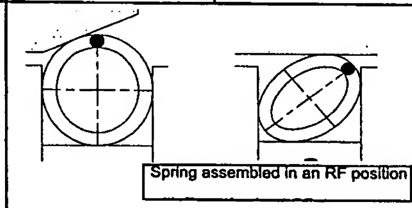
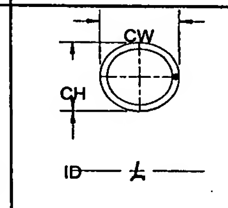
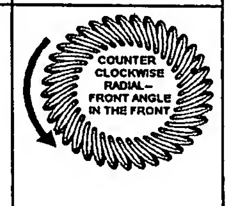
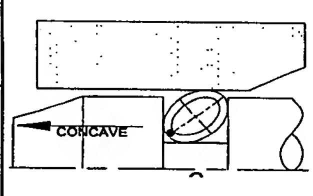
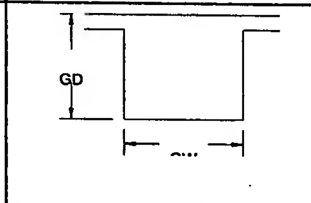
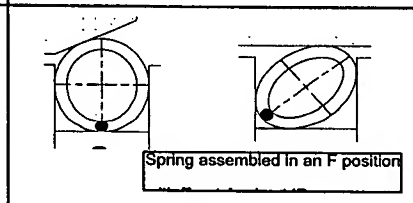
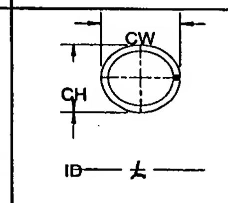
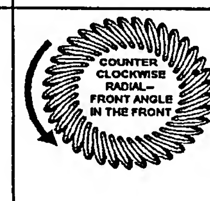
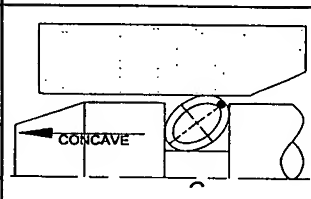
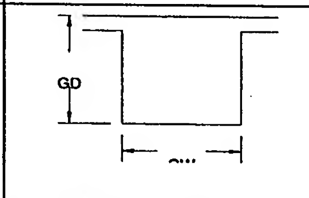
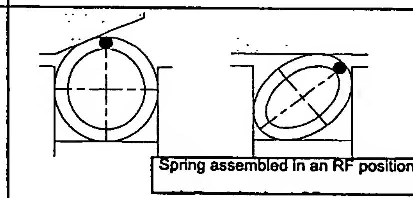
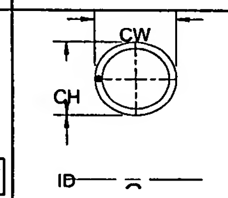
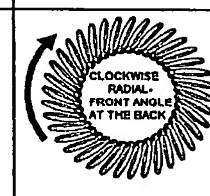
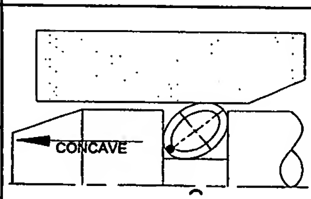
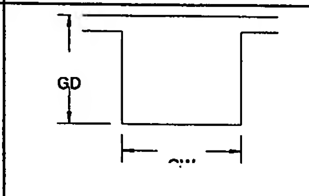
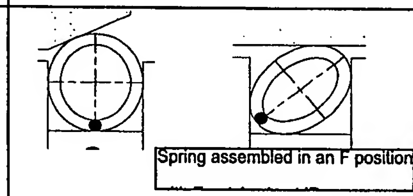
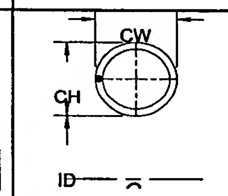
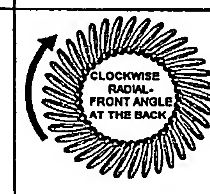
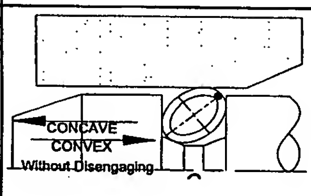
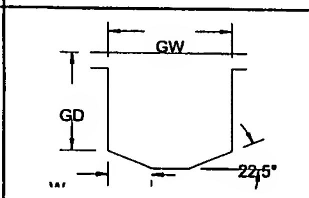
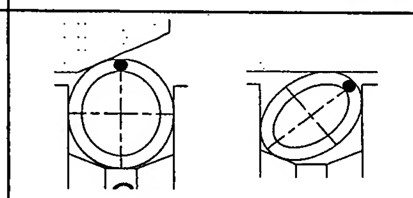
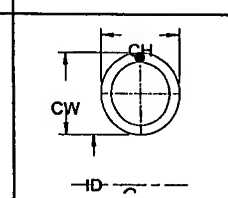
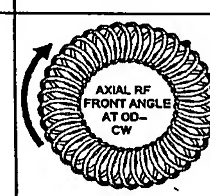
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs / Deflected Springs	Spring Types	Coil Directions
Flat-Bottom Axial Groove with Counter Clockwise Radial Spring Mounted in RF Position GW<CH					
Flat-Bottom Axial Groove with Counter Clockwise Radial Spring Mounted in F Position GW<CH					
Flat-Bottom Axial Groove with Clockwise Radial Spring Mounted In RF Position GW<CH					
Flat-Bottom Axial Groove with Clockwise Radial Spring Mounted In F Position GW<CH					
V-Bottom Groove with RF Axial Spring GW<CH					

TABLE 2c

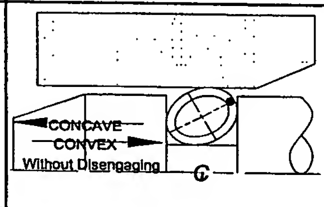
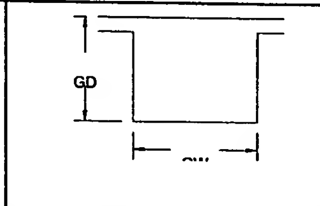
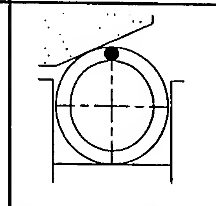
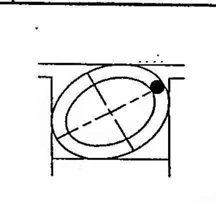
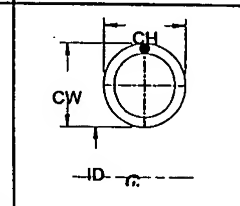
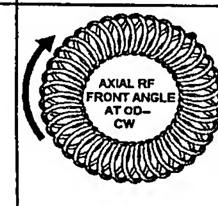
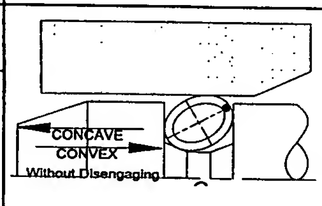
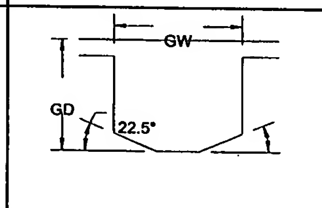
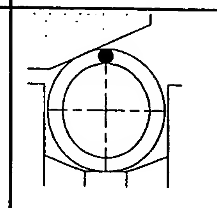
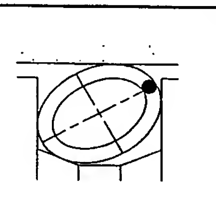
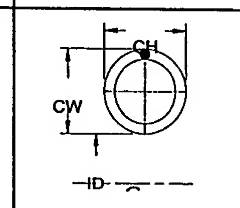
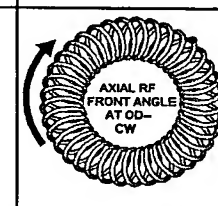
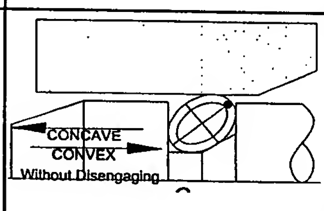
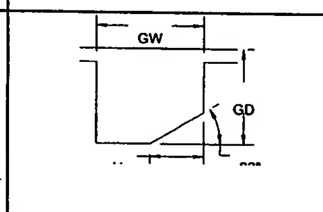
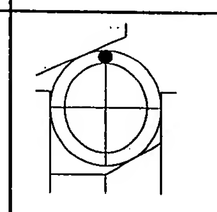
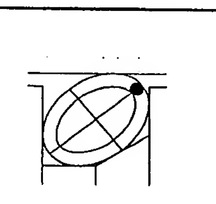
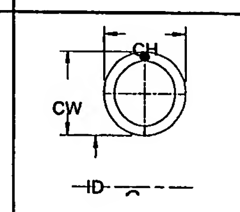
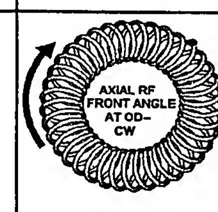
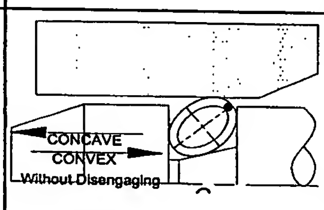
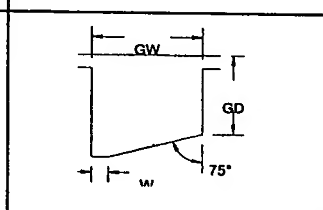
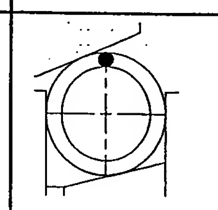
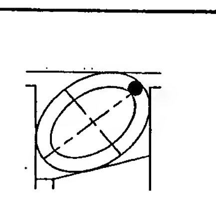
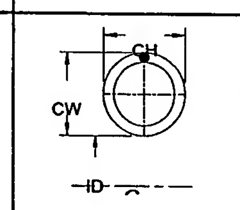
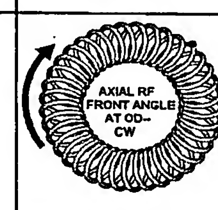
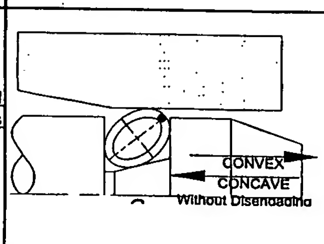
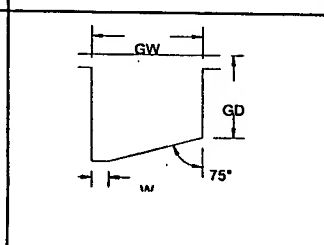
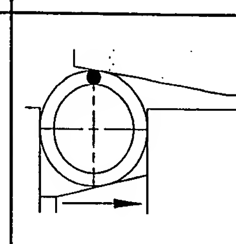
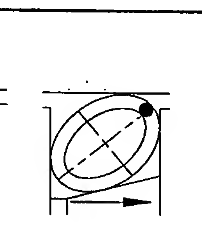
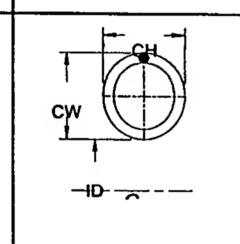
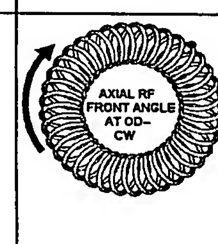
Types of Grooves- Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Flat-Bottom Groove with RF Axial Spring GW>CH						
V-Bottom-Tapered Groove with RF Axial Spring GW>CH						
Semi-Tapered Groove with RF Axial Spring GW<CH						
Tapered-Bottom Groove with RF Axial Spring GW<CH						
Tapered-Bottom Groove with RF Axial Spring–Shaft Travels in the Convex Direction GW<CH						

TABLE 2d

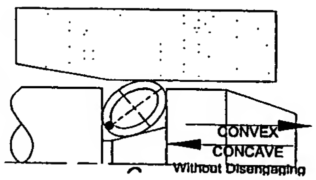
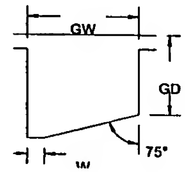
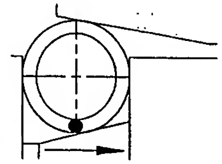
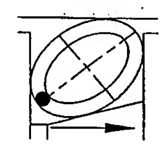
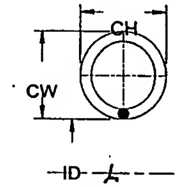
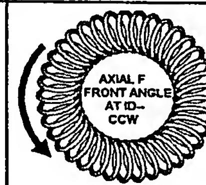
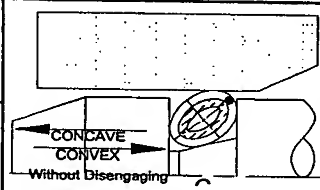
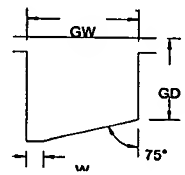
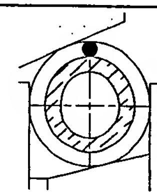
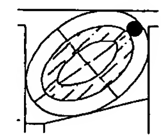
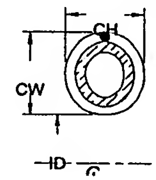
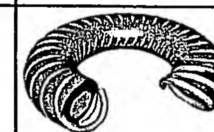
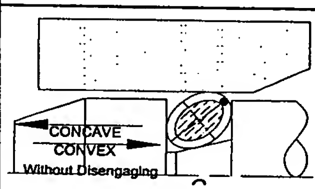
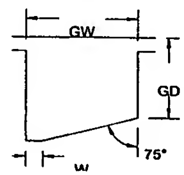
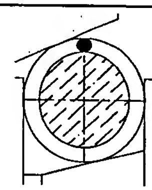
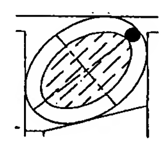
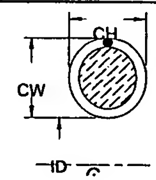
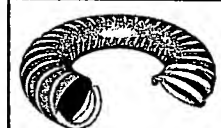
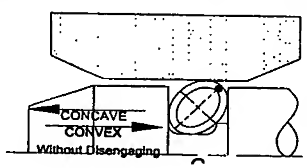
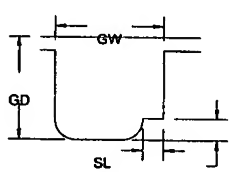
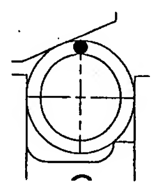
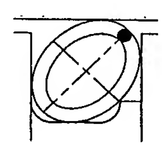
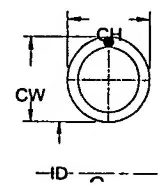
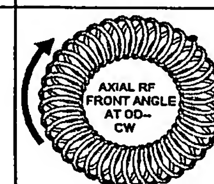
Types of Grooves- Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Tapered-Bottom Groove with F Axial Spring–Shaft Travels In the Convex Direction GW<CH						
Tapered-Bottom Groove with RF Axial Spring Filled with Elastomer (Hollowed) GW<CH						
Tapered-Bottom Groove with RF Axial Spring Filled with Elastomer (Solid) GW<CH						
Round-Bottom Groove with RF Axial Spring GW<CH						

TABLE 2e

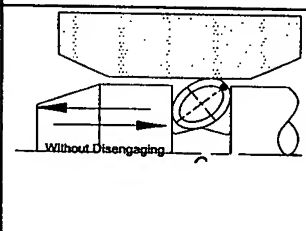
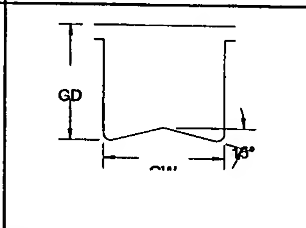
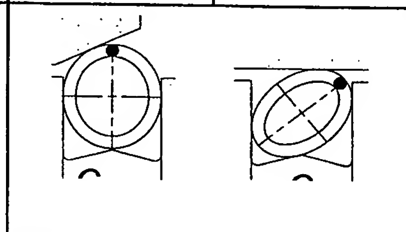
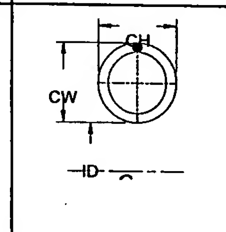
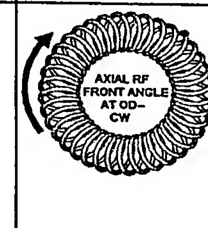
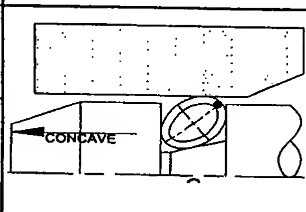
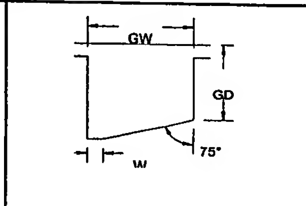
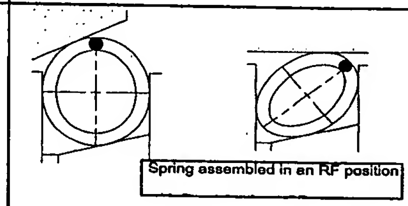
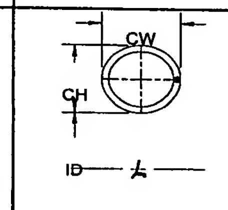
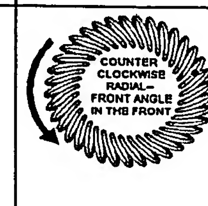
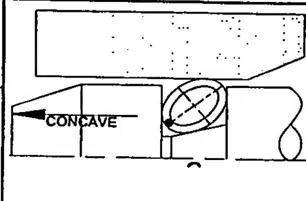
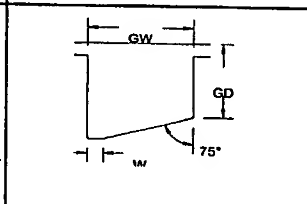
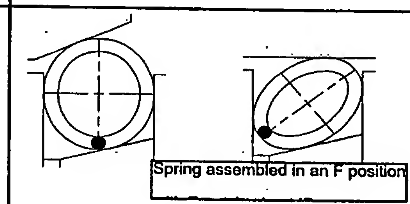
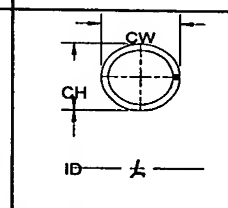
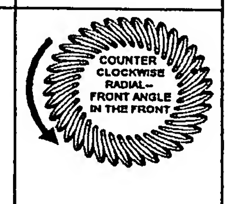
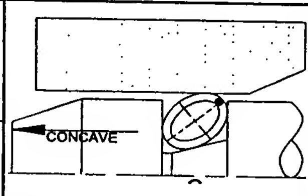
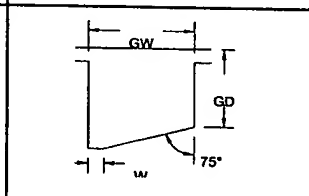
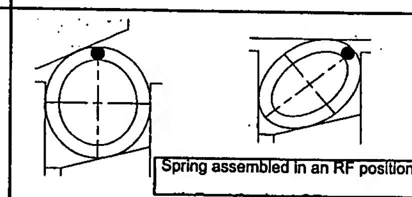
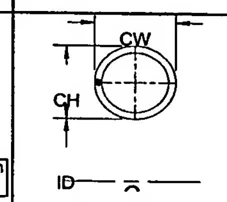
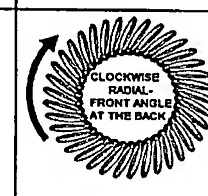
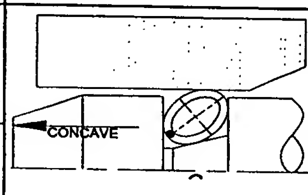
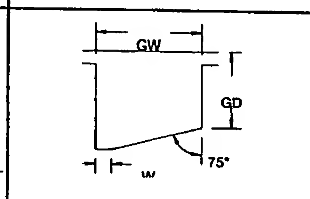
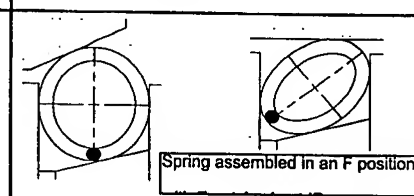
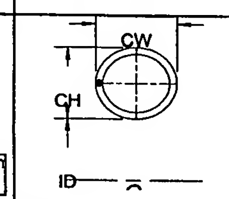
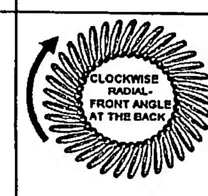
Types of Grooves- Types of Springs	Design Types	Groove Details	Free Springs / Deflected Springs	Spring Types	Coil Directions
Inverted-V-Bottom Groove with RF Axial Spring GW<CH					
Tapered-Bottom Groove with Counter Clockwise Radial Spring Mounted in RF Position GW<CH					
Tapered-Bottom Groove with Counter Clockwise Radial Spring Mounted in F Position GW<CH					
Tapered-Bottom Groove with Clockwise Radial Spring Mounted in RF Position GW<CH					
Tapered-Bottom Groove with Clockwise Radial Spring Mounted in F Position GW<CH					

TABLE 2f

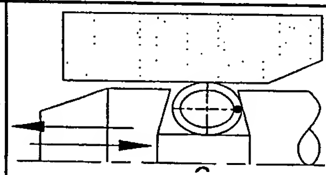
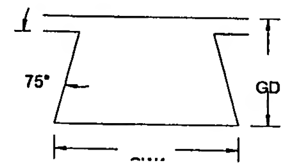
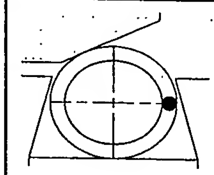
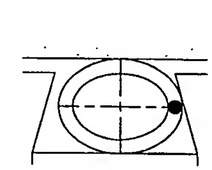
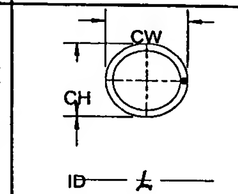
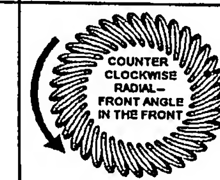
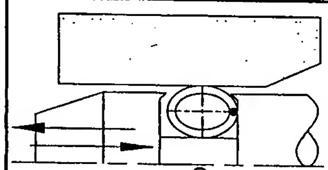
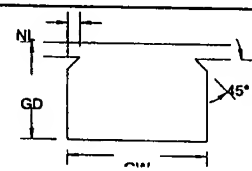
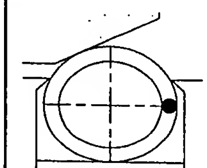
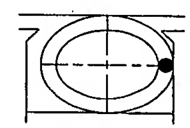
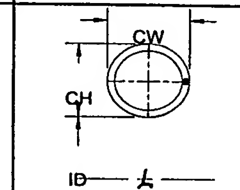
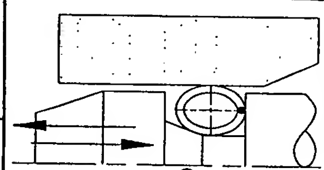
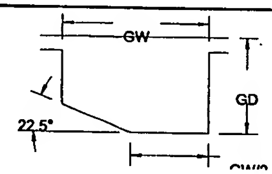
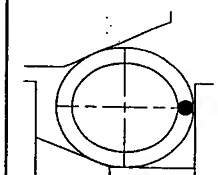
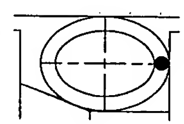
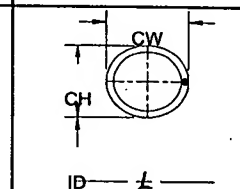
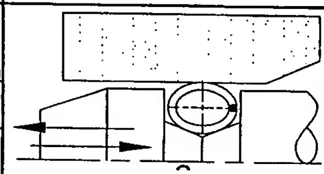
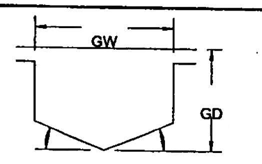
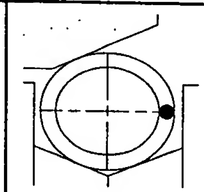
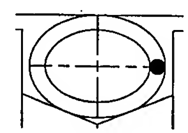
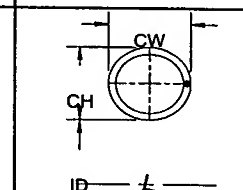
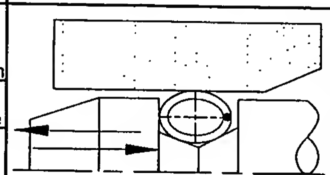
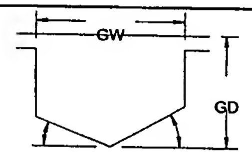
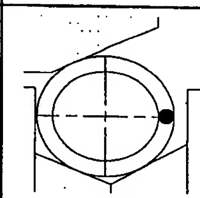
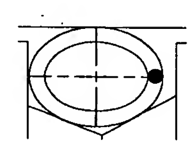
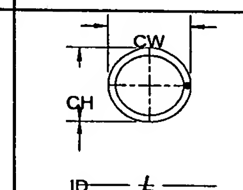
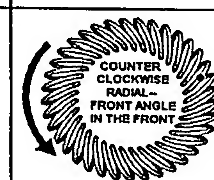
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
Dovetail Groove with Counter-clockwise Radial Spring GW>CW						
Dovetail Groove with Counter-clockwise Radial Spring GW>CW						
Angle 0°-22.5°-Bottom Groove with Counter-clockwise Radial Spring GW>CW						
Angle 22.5°-22.5°-Bottom Groove with Counter-clockwise Radial Spring GW>CW						
Angle 30.0°-22.5°-Bottom Groove with Counter-clockwise Radial Spring GW>CW						

TABLE 2g

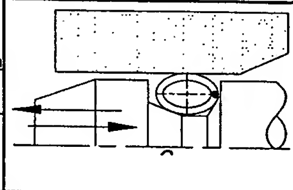
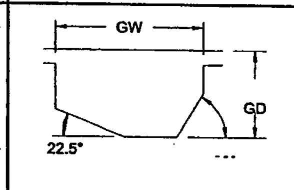
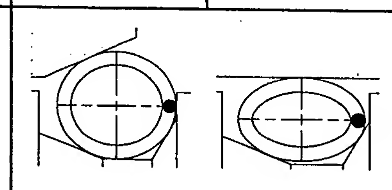
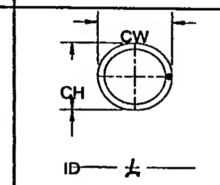
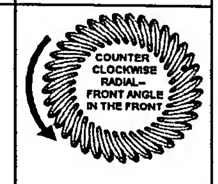
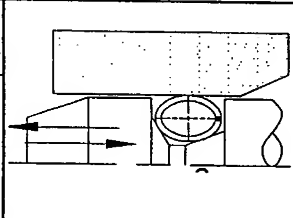
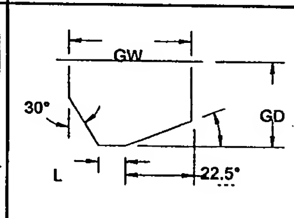
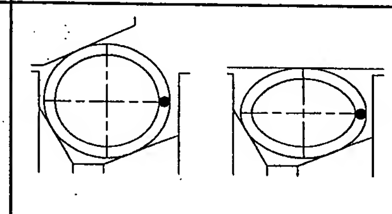
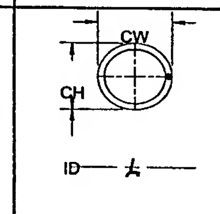
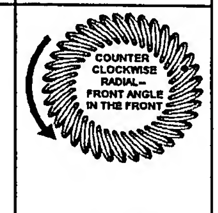
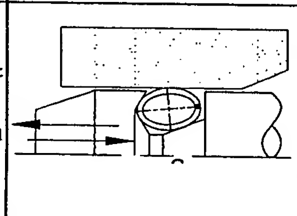
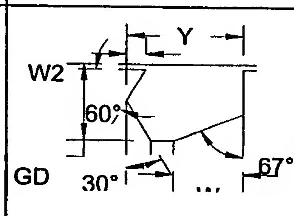
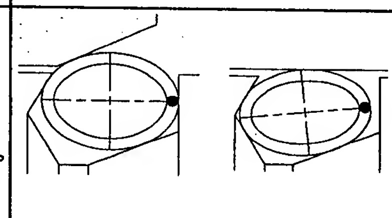
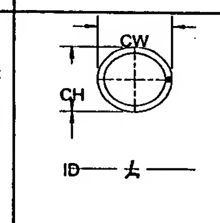
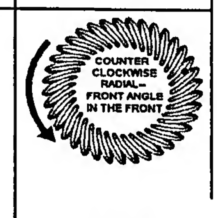
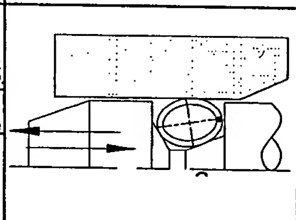
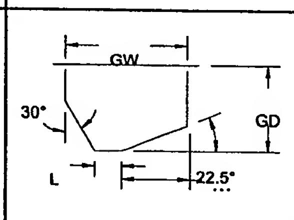
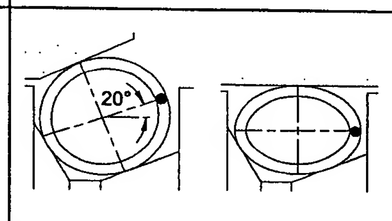
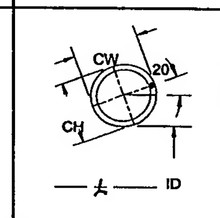
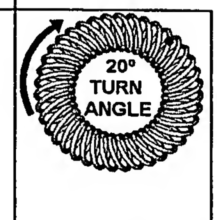
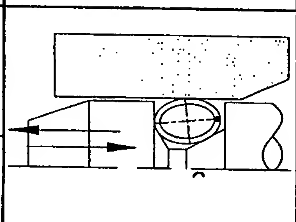
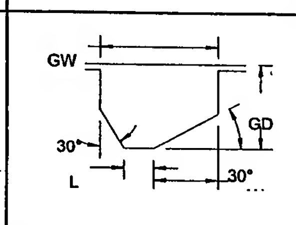
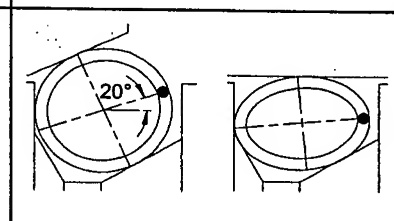
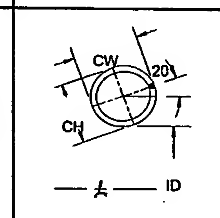
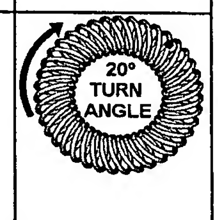
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs / Deflected Springs	Spring Types	Coil Directions
Angle 60.0°-22.5°-Bottom Groove with Counter-clockwise Radial Spring GW>CW					
Special V Bottom with 22.5° and 30° Angles Groove with Counter-clockwise Radial Spring GW>CW					
Special-V-Bottom-with-67°-30°-60°-Angles Groove with Radial Spring GW>CW					
Special-V-Bottom-with-22.5°-and-30° Angles Groove with 20° turn angle spring GW > CW					
Special-V-Bottom-with-30°-and-30°-Angles Groove with 30° turn angle spring GW > CW					

TABLE 2h

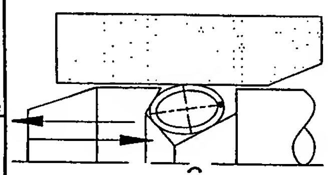
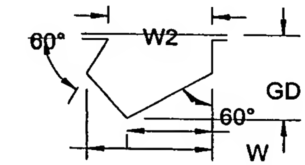
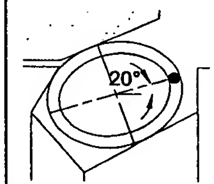
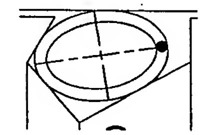
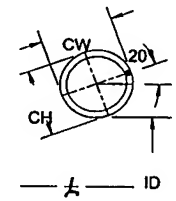
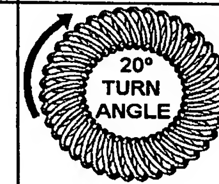
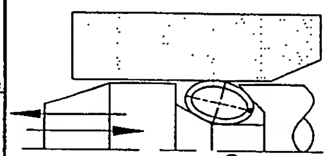
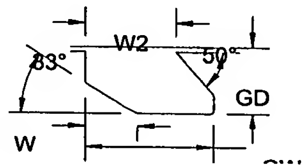
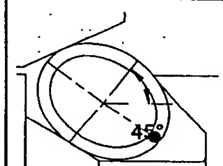
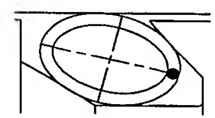
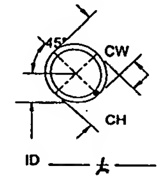
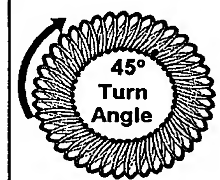
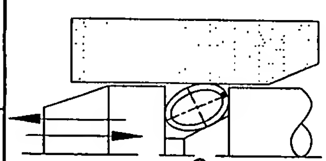
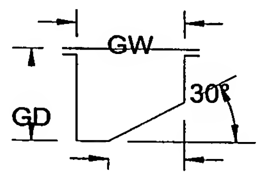
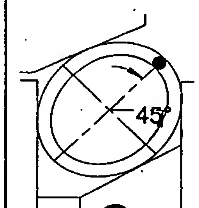
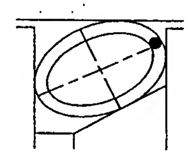
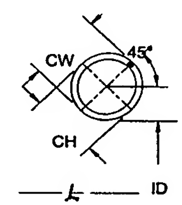
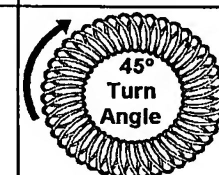
Types of Grooves-Types of Springs	Design Types	Groove Details	Free Springs	Deflected Springs	Spring Types	Coil Directions
<u>Special-V-Bottom-with-60°-and-60°-Angles Groove with 20° turn angle spring</u> <u>GW > CW</u>						
<u>Special Groove with 45° turn angle spring</u> <u>GW>CW</u>						
<u>Special-Tapered-Bottom-with 30°-Angle Groove with 45° turn angle spring</u> <u>GW<CW</u>						

Table 3

Running Force Comparison: Shaft Inserted in the Concave Direction vs. Shaft Inserted in the Convex Direction for Axial F and RF Springs.

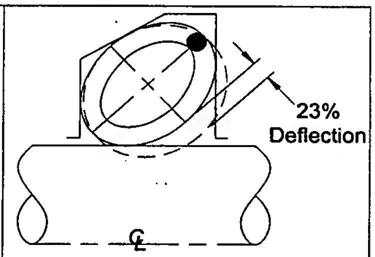
	RFX37367	RFX37367		FX37367	FX37367	
Item #	Running Force in The Concave Direction (lbs)	Running Force in The Convex Direction (lbs)	Percent Difference in Running Force %	Running Force in The Concave Direction (lbs)	Running Force in The Convex Direction (lbs)	Percent Difference in Running Force %
1	0.24	0.61		0.27	2.56	
2	0.23	0.59		0.27	2.50	
3	0.24	0.55		0.27	2.39	
4	0.21	3.19		0.26	6.20	
5	0.21	0.36		0.26	6.11	
6	0.20	0.35		0.26	4.74	
7	0.23	1.57		0.27	2.93	
8	0.22	0.45		0.30	2.64	
9	0.23	0.43		0.28	2.47	
Average:	0.222	0.898	**304**	0.271	3.614	**1233**

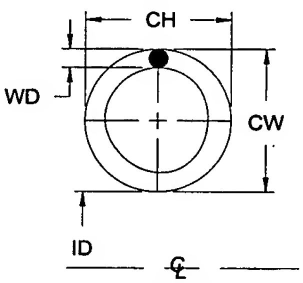
The 'F' springs in the convex direction produces substantially higher running force (1233%) than 'F' springs in the concave direction. In 'RF' springs, the running force in the convex direction is 304% higher than in the concave direction.

Table 4

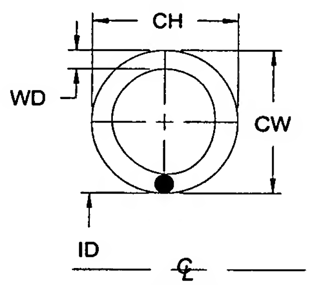
- For RF spring, shaft was inserted in the concave direction, traveled in the concave direction (Fig. 16a and Fig. 16b).
- For RF spring, shaft was inserted in the convex direction, traveled in the convex direction (Fig. 17a and Fig. 17b).
- For F spring, shaft was inserted in the concave direction, traveled in the concave direction (Fig. 16a and Fig. 16b).
- For F spring, shaft was inserted in the convex direction, traveled in the convex direction (Fig. 17a and Fig. 17b).

Spring Data:
Spring deflection: 23%

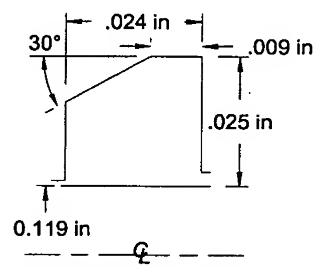




Spring Dimensions
RF Spring
CH = 0.026 in
CW = 0.027 in
WD = 0.0035 in
ID = 0.118 in



Spring Dimensions
F Spring
CH = 0.026 in
CW = 0.027 in
WD = 0.0035 in
ID = 0.118 in



Housing Groove Dimensions

Table 5

Running Force Comparison of Springs with Various ID Mounted on a Housing

Test Number	Spring	Spring ID (in)	Spring OD (in)	Shaft Diameter (in)	Bore Diameter (in)	Running Force (g)	% of Change in Average Running Force
1	104LB-(.341)	0.341	0.513	0.371	0.498	165	
	104LB-(.341)	0.341	0.513	0.371	0.498	165	
	104LB-(.341)	0.341	0.513	0.371	0.498	170	
	104LB-(.341)	0.341	0.513	0.371	0.498	170	
	104LB-(.341)	0.341	0.513	0.371	0.498	161	
	Average					166	BASE
2	104LB-(.518)	0.518	0.690	0.371	0.498	121	
	104LB-(.518)	0.518	0.690	0.371	0.498	101	
	104LB-(.518)	0.518	0.690	0.371	0.498	124	
	104LB-(.518)	0.518	0.690	0.371	0.498	120	
	104LB-(.518)	0.518	0.690	0.371	0.498	121	
	Average					117	-29
3	104LB-(.550)	0.550	0.722	0.371	0.498	112	
	104LB-(.550)	0.550	0.722	0.371	0.498	114	
	104LB-(.550)	0.550	0.722	0.371	0.498	114	
	104LB-(.550)	0.550	0.722	0.371	0.498	113	
	104LB-(.550)	0.550	0.722	0.371	0.498	103	
	Average					111	-33

Stretching the spring from the ID results in higher running force.
Compressing the spring from the OD results in lower running force

Table 6

Running Force of Springs Compressed from th OD at Various D fl ction

Test No.	Springs	Number of Coils	Shaft Diameters (in)	Bore Diameters (in)	Perc nt Defl ction (%) Running Friction Forces (g)			
					10%	17%	25%	35%
1	104MB(0.125)-SS-SOW	27	0.125	0.273,0.263, 0.249,0.233	179	233	359	1288 (butting)
2	104MB(0.250)-SS-SOW	44	0.250	0.398,0.388, 0.374,0.358	343	422	479	2912 (butting)
3	104MB(0.500)-SS-SOW	74	0.500	0.648, 0.638, 0.624, 0.608	570	679	705	1302 (butting)
4	104MB(1.000)-SS-SOW	143	1	1.148,1.138, 1.124,1.108	1160	1361	1528	2523 (butting)

Compressing the coils from the OD while maintaining the same spring and shaft diameters results in lower running force. Spring butts at a smaller percent deflection than in (Fig. 3-25a).

Table 7

Running Force of Springs Compressed from the ID at Various Deflection

Test No.	Springs	Number of Coils	Shaft Diameters (in)	Bore Diameters (in)	Percent Deflection (%) Running Friction Forces (g)			
					10%	17%	25%	35%
1	104MB(0.125)-SS-SOW	27	0.143, 0.153, 0.167, 0.183	0.291	324	315	389	442
2	104MB(0.250)-SS-SOW	44	0.268,0.278,0.292,0.308	0.416	368	382	541	594
3	104MB(0.500)-SS-SOW	74	0.518, 0.528, 0.542, 0.558	0.666	814	871	901	979
4	104MB(1.000)-SS-SOW	143	1.018,1.028,1.042,1.058	1,166	1433	1473	1768	1683

Stretching the spring ID to the shaft diameter and compressing the coils from the ID results in higher running force. Stretching the

Table 8

Running Force of RF Springs vs. Running Force of F Springs Mounted in a Housing

Spring No.	Spring Series	Spring ID (in)	Number of Coils per Spring	% of Deflection	Average Running Force (g)	% of Change in Average Running Force
1	F104MC	0.625	85	25	722	
2	F104MC	0.625	85	25	643	
3	F104MC	0.625	85	25	694	
Average					686	BASE
1	RF104MC	0.625	85	25	639	
2	RF104MC	0.625	85	25	652	
3	RF104MC	0.625	85	25	555	
Average					615	-10

RF springs develop 10% to 30% lower running force than F springs under the same conditions. Values vary with Spring/Groove parameters.

Table 9

Running Force of RF Springs vs. Running Force of F Springs Mounted in a Piston

Spring No.	Spring Series	Spring ID (in)	Number of Coils per Spring	% of Deflection	Average Running Force (g)	% of Change in Average Running Force
1	F104MC	0.625	85	25	612	
2	F104MC	0.625	85	25	585	
3	F104MC	0.625	85	25	626	
4	F104MC	0.625	85	25	594	
5	F104MC	0.625	85	25	585	
Average					601	BASE
1	RF104MC	0.625	85	25	452	
2	RF104MC	0.625	85	25	562	
3	RF104MC	0.625	85	25	465	
4	RF104MC	0.625	85	25	525	
5	RF104MC	0.625	85	25	505	
Average					502	-16

RF springs develop 10% to 30% lower running force than F springs under the same conditions. Values vary with Spring/Groove parameters.

Table 10

Axial RF Spring Diameters vs. Running Force

Spring No.	Spring ID (in)	Spring Series	Number of Coils per Spring	% of Deflection	Average Running Force (g)	% of Change in Average Running Force
1	0.625	RF104MC	85	25	683	
2	0.625	RF104MC	85	25	675	
3	0.625	RF104MC	85	25	590	
4	0.625	RF104MC	85	25	677	
5	0.625	RF104MC	85	25	613	
Average					648	BASE
1	0.650	RF104MC	88	25	628	
2	0.650	RF104MC	88	25	557	
3	0.650	RF104MC	88	25	561	
4	0.650	RF104MC	88	25	559	
5	0.650	RF104MC	88	25	551	
Average					571	-12
1	0.675	RF104MC	91	25	538	
2	0.675	RF104MC	91	25	544	
3	0.675	RF104MC	91	25	536	
4	0.675	RF104MC	91	25	621	
5	0.675	RF104MC	91	25	582	
Average					564	-13

Increasing the spring ID and number of coils while maintaining the same dimensions of the shaft and housing results in lower running force of about 10% to 30% depending on spring parameters.

Table 11

Axial RF Spring Diameters vs. Running Force

Spring No.	Spring ID (in)	Spring Series	Number of Coils per Spring	% of Deflection	Average Running Force (g)	% of Change in Average Running Force
1	0.625	F104MC	85	25	720	
2	0.625	F104MC	85	25	695	
3	0.625	F104MC	85	25	690	
4	0.625	F104MC	85	25	760	
5	0.625	F104MC	85	25	725	
Average					**718**	**BASE**
1	0.650	F104MC	88	25	625	
2	0.650	F104MC	88	25	620	
3	0.650	F104MC	88	25	625	
4	0.650	F104MC	88	25	600	
5	0.650	F104MC	88	25	625	
Average					**619**	**-14**
1	0.675	F104MC	91	25	585	
2	0.675	F104MC	91	25	610	
3	0.675	F104MC	91	25	625	
4	0.675	F104MC	91	25	540	
5	0.675	F104MC	91	25	570	
Average					**586**	**-18**

Increasing the spring ID and number of coils while maintaining the same dimensions of the shaft and housing results in lower running force of about 10% to 30% depending on spring parameters.